Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matters of	
International Comparisons and Consumer Survey Requirements in the Broadband Data Improvement Act	GN Docket No. 09-47
A National Broadband Plan for Our Future	GN Docket No. 09-51
Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act	GN Docket No. 09-137

Comments of 3G Americas—NBP Public Notice #6

3G Americas, LLC, the leading industry association in the Americas representing the GSM family of technologies, including HSPA and LTE, submits these comments in response to the Commission's Public Notice ("*Notice 6*")[1] in the above-referenced proceeding concerning the Commission's development of a National Broadband Plan pursuant to the American Recovery and Reinvestment Act of 2009.[2] 3G Americas requests that the Commission allocate spectrum for mobile broadband that has been recommended by the International Telecommunications Union for IMT Advanced, since globally identified spectrum benefits U.S. consumers of mobile broadband by allowing

1 Comment Sought on Spectrum for Broadband, NBP Public Notice #6, GN Docket Nos. 09-47, 09-51, and 09-137 (Sept. 23, 2009)..

2 American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, 123 Stat. 115 (2009).

carriers economies of scale in infrastructure, devices and the delivery of innovative applications

3G Americas has a broad membership of leading wireless operators and vendors promoting, facilitating, and advocating the deployment of the GSM family of technologies throughout the Americas.[3] In these comments, 3G Americas seeks to answer the questions posed in *Notice 6* by the Commission about the sufficiency of current spectrum allocations.

Response to Questions

1. What is the ability of current spectrum allocation to support next-generation build-out and the anticipated surge in demand and throughput requirements?

a. How should we think about the capacity of existing allocations and their ability to support growth in wireless broadband? How can we further characterize the impact of a shortage of spectrum available for mobile wireless services?

1. Existing Allocations and the Move to Increase Allocations for Mobile Broadband.

The U.S. has been, and should continue to be, the world leader in wireless mobile broadband. Because of U.S. leadership in this area, the American public has been fortunate enough to "use wireless service at a much higher rate than their counterparts in other countries."[4]

Despite its traditional leadership, the U.S. has not acted as quickly as have most European countries to provide spectrum for the exploding growth of mobile broadband.

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[3] 3G Americas Board of Governor members include Alcatel-Lucent, Andrew, AT&T, Cable & Wireless, Ericsson, Gemalto, HP, Huawei, Motorola, Nortel Networks, Nokia, Openwave, Research in Motion, Rogers, T-Mobile USA, Telcel, Telefónica, and Texas Instruments.

[4] Comments of T-Mobile, USA, Inc. at 18, WT Docket No. 09-66, GN Docket Nos. 09-157 and 09-51 (filed Sept. 30, 2009) ("T-Mobile Comments").

As T-Mobile and CTIA have explained to the Commission, most European countries have and are continuing to make plans to allocate additional spectrum for wireless services. For example:

> The U.K. currently has 352.8 MHz assigned for commercial wireless spectrum and has 355 MHz of spectrum suitable for commercial mobile services, including an auction of 2.6 GHz spectrum expected in 2010. Spain has announced plans to begin allocating spectrum in the 2.6 GHz and 3.5 GHz bands by the end of 2009, including moving spectrum in the 900 MHz and 1800 MHz from 2G to 3G use. Italy and Belgium have announced plans to sell or auction 3G spectrum, and during 2008, Scandinavian countries held several auctions in the 1.8, 2.3, 2.6 and 10 GHz bands. According to CTIA, France currently has 374.6 MHz allocated for commercial wireless use and has 72 MHz of potentially useable spectrum in the pipeline. Germany's current commercial wireless spectrum allocation sits at 305 MHz, and the country has identified 340 MHz of additional spectrum for wireless services.[5]

In the United States, by contrast, only a limited amount of spectrum – 50 MHz – is in the "pipeline" – that is allocated for commercial use and waiting to be assigned.[6] Beyond this AWS-2, AWS-3 and D-block spectrum, no additional spectrum is actively being considered for allocation for licensed mobile broadband.[7]

By 2010, "mobile broadband penetration will surpass fixed penetration globally. Countries that are behind the curve in spectrum allocation will lag behind as a lack of spectrum will delay the launch of broadband services."[8] The United States must act now to continue to lead the world in mobile broadband.

2. *Growth of Demand for Mobile Broadband and the Necessity of Additional Spectrum.*

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5 *Id*. at 18-19 (internal citations and quotation marks omitted).

6 *Id*. at 20.

7 *Id*.

8 Chetan Sharma Consulting, *Managing Growth and Profits in the Yottabyte Era* 16 (2009), http://www.chetansharma.com/yottabyteera.htm.

This is a critical time in the industry. Networks technologies must enable more efficient use of spectrum, but the Commission also must supply the spectrum needed for the industry to meet the needs of consumers. Over the last several decades, mobile services have grown at an exponential rate.[9] With the increased demand for wireless data, traffic volume has reached saturation, with the consensus being that wireless data traffic volume is "more than doubling" every year.[10] AT&T projects that by 2018, 3G/4G traffic will expand by a factor of at least 250 and possibly as high as 600.[11]

The need for additional spectrum already has been recognized by the Commission, with Blair Levin, head of the Commission's National Broadband Plan task force, noting that a "key input" in the plan "is spectrum, and everyone agrees there is not enough of it. Moreover, demand curves from new uses by smartphones suggest a massive increase ahead for that input."[12]

The chart below depicts the anticipated growth of broadband through 2014, and in particular, the explosive growth of mobile broadband.[13]

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[9] Comments of CTIA-The Wireless Association® at 69-71, GN Docket Nos. 09-157 and 09-51 (filed Sept. 30, 2009)("CTIA Comments").

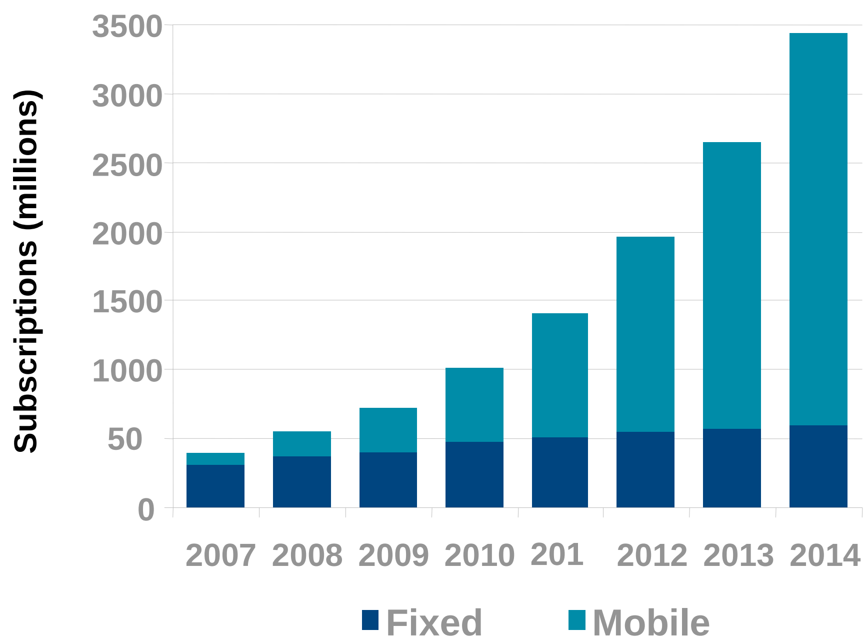
[10] *Id*. at 71.

[11] Rysavy Research, *Mobile Broadband Spectrum Demand* 12-13 (2008).

[12] Kim McAvoy, *FCC Floats Cash-For-TV Spectrum Scheme*, TV NewsCheck, Oct. 21, 2009, *available at* http://www.tvnewscheck.com/articles/2009/10/21/daily.4/.

[13] Neville Ray, Chairperson, 3G Americas, *The Mobile Braodband Evolution and Revolution* (2009).

Projected Broadband Growth



It has become evident that "[a] technological limit is approaching for which more spectrum is the only solution."[14] If innovation and the corresponding provision of new and innovative services to the American public is to continue, there is no escape from the conclusion that services must have access to additional spectrum.[15]

This is the conclusion that also has been reached by the International Telecommunication Union ("ITU"), which analyzed how much additional spectrum will be needed to support commercial wireless services in members' markets. The ITU has concluded that, including currently assigned spectrum, spectrum requirements by 2020

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[14] T-Mobile Comments at 18.

[15] CTIA Comments 69-71.

for a *single network* within a *single country* will range from 1280-1720 MHz.[16] The NGNM Alliance extrapolated from the ITU's forecast to determine that Region 2, the Americas, will need a net additional 557-997 MHz by 2020.[17] 3G Americas provides a more comprehensive analysis of these studies in a white paper that is attached as Exhibit 1 to these comments.

2. What spectrum bands are best positioned to support mobile wireless broadband?

a. What is the current stock of spectrum available to support mobile wireless broadband? What is the proper methodology to compute this quantity?

3G Americas urges the Commission to conduct a comprehensive spectrum inventory to identify bands that can be allocated for mobile broadband. As an initial step in this inventory, the Commission should look to the international allocation of spectrum for mobile broadband to attempt to achieve global harmonization. 3G Americas discusses global harmonization of spectrum in greater detail below in response to question 2.d.

Another critical aspect of the spectrum inventory should be to identify government spectrum usage, because it is likely that underutilized spectrum currently assigned to the Federal government will be a critical source for spectrum that can be repurposed. The inventory should not simply identify bands, but research the intensity of

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16 International Telecommunication Union, *Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced*, ITU-R Report M.2078 (2006); 3G Americas, LLC, *3GPP Technology Approaches for Maximizing Fragmented Spectrum Allocations* 20 (2009), http://www.3gamericas.org/documents/3GA%20Underutilized%20Spectrum_Final_7_23_092.pdf ("3G Americas Fragmented Spectrum White Paper").

17 *See* A White Paper Update by NGMN Alliance, *Next Generation Mobile Networks Spectrum Requirements Update* (October 5, 2009), available at http://www.ngmn.org/fileadmin/user_upload/Downloads/Technical/NGMN-WP_Spectrum_Requirements.pdf.

use of bands, on a temporal and regional basis. For example, some federal spectrum use is limited to a handful of stations, yet is assigned on a national basis.

Since it is established Federal policy that government users should rely on commercial radio services where possible, federal users would be beneficiaries of repurposed spectrum. For a variety of reasons, the public is well served by opening underutilized government spectrum for non-government use.

The spectrum inventory should also identify within existing commercial allocations where the spectrum can be used more efficiently.

b. Which other spectrum bands might be most appropriate to repurpose to support mobile wireless broadband? Would these bands support shared use or would they need to be reallocated? What specific mechanisms should be used to facilitate transitions from incumbents?

In ascertaining which spectrum bands are best positioned to support mobile broadband, the Commission should keep in mind certain considerations.

First, spectrum allocated for commercial mobile wireless broadband should, in general, reside below 4.2 GHz to ensure that it can be used economically to deliver mobile broadband services. Below that threshold, certain bands have additional beneficial characteristics for advanced mobile services. For example, the 3.4-3.6 GHz band was identified in 2007 at the ITU's World Radiocommunication Conference for mobile use.[18] Use of the 3.4 – 3.6 GHz band could therefore benefit U.S. mobile users through economies of scale more readily achieved through global spectrum allocations.

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[18] International Telecommunication Union, *World Radiocommunication Conference: Provisional Final Acts* (2007) (adding in Region 1, international footnote 5.AAA designating entire band for mobile; adding in Region 2, international footnote 5.ZZZ designating 3400-3500 MHz for mobile; and adding in Region 3, international footnotes 5.AAA1 and 5.BBB to designate 3400-3500 MHz for mobile and 5.CCC 3500-3600 MHz for mobile); International Telecommunications Union, *Results of WRC-07* 11 (2008), http://www.itu.int/ITU-R/space/support/workshop/doc_presentation_en/WRC07%20results_FL.pdf.

Second, spectrum allocated for commercial mobile broadband should be as contiguous as possible. Current allocations are primarily based on 5 and 10 MHz blocks. Such allocations may have been appropriate for second, and even third, generation data services, but they are not sufficient to support advanced data services. Wider bandwidth allocations are better suited for future, data-intensive wireless broadband services. Blocks of 2x20 MHz spectrum pairs would be an improvement, but even that may not be enough spectrum for future broadband use given the current trajectory of demand. It is instructive that European regulators are planning 2x30 MHz pairs for LTE wireless deployment.

Third, for reasons elaborated below in response to question 2.d, spectrum allocated for mobile broadband in the U.S. should be globally harmonized to the greatest extent possible. Globally harmonized spectrum provides the critical mass of customers to network vendors to produce network equipment at a more affordable incremental unit price, which, in turn, allows operators to deploy advanced networks more rapidly. For the same reasons, harmonized spectrum will result in lower cost handsets.

The spectrum inventory is a good first step, but is insufficient without a concrete framework for the relocation process, including a firm timeframe for decision-making regarding relocating users. Firm deadlines are essential both to expedite the deployment of mobile broadband services and to avoid creating disincentives for robust bidding in future spectrum auctions.[19] This is the same approach recommended by NTIA's public

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[19] *See* Comments of 3G Americas, LLC, NTIA Docket No. 0906231085-91085-01 (filed Aug. 21, 2009).

advisors, the Commerce Spectrum Management Advisory Committee, with regard to the Commercial Spectrum Enhancement Act.[20]

d. Are there bands usable for mobile wireless broadband in other countries that might also be used in the United States? Which bands? What would be the benefit and viability of making these bands available in the United States?

3G Americas urges the Commission to allocate spectrum for mobile broadband in a manner consistent with global spectrum allocations identified on a global or regional basis by 3GPP, CITEL, and the ITU, to the greatest extent possible. Allocating spectrum to increase global harmonization will benefit the public in numerous ways. U.S. consumers will benefit from lower-cost handsets and manufacturers will be able to take advantage of global economies of scale instead of building network equipment solely for the U.S. market. American consumers will benefit from a greater number of innovative applications that will arise from a global development base, offered over lower incremental-cost handsets. An early alignment of spectrum in various markets will expedite the deployment of LTE Advanced, thereby benefitting the U.S. public by facilitating the delivery of advanced, high-speed mobile broadband to handsets and other mobile devices.

As an immediate step, the Commission can pair 25 MHz of contiguous spectrum in the 1755-1780 MHz government band with the 25 MHz "extended" AWS-3 (2155-2180 MHz) band. This would harmonize those bands within the U.S. with recommendations from 3GPP, CITEL, and the ITU. Specifically, the ITU recommends that for advanced wireless services, administrations pair 2110-2170 MHz as a downlink

[20] Commerce Spectrum Management Advisory Committee, *Transition Report* 30-31 (2008), http://www.ntia.doc.gov/advisory/spectrum/meeting_files/CSMAC_Transition_Report_(121208b_-_CLEAN).pdf.

band with an uplink band at either 1920-1980 MHz or 1710-1770 MHz.[21] In Region 2, the Americas, CITEL has also endorsed pairing the 2110-2170 MHz band as a downlink band with the 1710-1770 MHz uplink band.[22] 3GPP has recommended international allocation of 2110-2170 as a downlink band paired with 1710-1770 as an uplink band.[23] If the Commission pairs the 1755-1780 MHz government band with 2155-2180 MHz, American consumers will realize the benefits of rapid deployment of mobile broadband and advanced services, as well as more affordable handsets.

Conclusion

It is beyond argument that more spectrum than currently allocated is required to meet the demand of the American public for mobile broadband. Providing this essential resource for mobile broadband must be a key piece of the National Broadband Plan. 3G Americas urges the Commission to conduct a spectrum inventory to identify underutilized spectrum – particularly when that spectrum meshes with global allocations for mobile broadband – and to reallocate such spectrum for commercial mobile broadband. This reallocation should be of spectrum below 4.2 GHz and should contain contiguous blocks of sufficient bandwidth to meet the needs of new, data-intensive advanced services. Finally, the Commission should, to the extent possible, harmonize allocations of spectrum for mobile broadband with existing global recommendations so

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21 International Telecommunication Union, *Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications-2000 (IMT-2000) in the bands 806-960 MHz, 1710-2025 MHz, 2110-2200 MHz and 2500-2690 MHz,* Recommendation ITU-R M.1036-3 at 6-7 (2007).

22 *See* CITEL, XXI Meeting of Permanent Consultative Committee III: Radiocommunications, *Final Report* 21 (2002) (Option 5, "Mobile transmit band 1710-1770 MHz, paired with the global base transmit band 2110-2170 MHz, consistent with a duplex separation of 400 MHz."), http://www.citel.oas.org/pcc3_old/final/P3-2371r2_i.doc.

23 3G Americas Fragmented Spectrum White Paper at 6-7.

that the American public can realize the benefits of rapid and cost-effective deployment of mobile broadband.

Respectfully submitted,

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October 23, 2009

EXHIBIT 1

3GPP Technology Approaches for Maximizing Fragmented Spectrum Allocations

July 2009

TABLE OF CONTENTS

EXECUTIVE SUMMARY

An emerging challenge confronting spectrum stakeholders involves how to permit wider spectrum usage by operators using various technologies, while at the same time maximizing use of “fragmented” or non-standard spectrum bands.

The FCC AWS-III proceeding is perhaps the latest and the most visible example of this challenge, wherein the issue has centered on whether wireless operators employing different duplexing technologies can coexist in adjacent portions of the radio spectrum without some form of interference mitigation and/or more stringent limits on power and out of band emissions.

Going forward, in addition to AWS-III, the challenges of non-standard or fragmented spectrum bands may manifest themselves in other areas. Country specific allocations of the 2.6 GHz IMT band and “Digital Dividend” spectrum are other potential illustrations.

One of the most critical principles for spectrum managers around the globe is to allocate spectrum so that it aligns as much as possible with regional and global allocations. This permits leveraging scale economies that redound to the benefit of consumers both in terms of device costs and for international roaming. It also confers the possibility of time-to-market advantages for virtually all countries (save for China and India) whose populations would by themselves not effectively incent OEMs to build country-specific terminals in a timely and cost-efficient manner.

3G Americas’ objectives in developing this paper are to review these challenges and to describe 3GPP technology approaches and other practices that would help to address them. These include the development of dual carrier/dual band carrier aggregation (permitting the asymmetric pairing of uplink and downlink radio channels), coupled with the consensus on the need for safeguards and technical specifications in order to permit spectrum use by diverse service providers.

In doing so, 3G Americas’ intent is to situate these challenges in the context of the larger mobile broadband landscape, including technology directions, spectrum valuation and global harmonization.

Our goal is that this document will serve as a resource for a diverse readership, including service providers, vendors, policy makers, standards bodies, industry analysts and the media.

1. INTRODUCTION

1.1 DEFINING FRAGMENTED SPECTRUM

A threshold matter in undertaking the examination embodied by this document is to clarify what is meant by fragmented spectrum. In essence, we refer to spectrum that diverges from regional and/or global spectrum allocations, and consequently fails to benefit from scale economies and other advantages that flow from such spectrum alignment. The optimal utilization of these spectrum “islands” by countries, operators and consumers will in important respects be difficult to realize.

It bears emphasizing at the outset, however, that suboptimal spectrum allocations are not necessarily resources that cannot be put to use. In fact, standards bodies and other groups have and continue to develop innovative approaches in order to take advantage of these divergent assets. These technological advancements, however, cannot take the place of sound spectrum management, including the vital role played by spectrum harmonization. In fact, such advancements may presuppose that national spectrum managers have properly allocated nearby spectrum bands in such a way, for example, that they can be effectively paired or otherwise used with spectrum fragments. Nonetheless, these innovations can help to ensure that scarce spectral resources are put to use.

It is the principal aim of this paper to present and review some of the main techniques established and being developed by different entities in this area. Prior to doing so, mobile broadband should be situated in the larger macroeconomic and technological environment.

1.2 MOBILE BROADBAND

The world is at the precipice of the full-scale convergence of two powerful and sweeping forces: wireless mobility and broadband Internet access. Each of these forces on its own has made its mark indelibly on the global consumer consciousness. Wireless voice and data services have literally transformed telephony from a fixed place-to-place communications medium into mobile person-to-person interactions. The clunky telephones of yesterday have been revolutionized into the iconic wireless handsets of today. Similarly, the Internet has revolutionized the computer world, turning PC devices into interconnected windows to the World Wide Web. Totally new domains of information and interaction have been opened up in the process of creating the Internet.

Together these merging juggernauts, wireless mobility and the Internet, promise to unlock vast new capabilities for consumers, enterprises and governments. The mobile Internet clearly creates more value than merely the sum of its parts. The underpinning of this new domain is mobile broadband technology– bringing much of the rich fixed-line Internet experience to the mobile world. But technology alone cannot make mobile broadband happen. It must be coupled with an appropriate spectrum framework in order for mobile broadband to thrive in the marketplace. Because spectrum is such an important resource, optimal utilization is necessary and requires driving maximum efficiencies from all sources, both existing as well as impending allocations.

1.2.1 CATALYST FOR ECONOMIC GROWTH

The tremendous growth over the past two decades in wireless mobility and the Internet promises to compound when the two are coupled together on a mass market scale. While broadband is growing overall, the rate of growth for mobile broadband is outpacing broadband in general. Globally, fixed broadband is expected "to grow at a [compound annual growth rate] CAGR of 9 percent from 2008 to 2014, whereas mobile broadband computing will grow about three times as fast, totaling $69 billion by 2014 – 30 percent the size of fixed broadband."[1] Ovum has similarly concluded that users access the Internet via mobile broadband enabled laptops and handsets will generate revenues of $137 billion globally in 2014, 450 percent more than in 2008, and that during the same period mobile broadband users will climb from 181 million to over 2 billion worldwide.[2] Further, a recent report by McKinsey & Company noted that "mobile broadband is uniquely positioned to stimulate economic growth and welfare in areas that lack adequate fixed-line broadband infrastructure."[3] McKinsey estimates that "a 10 percent increase in broadband household penetration delivers a boost to a country's [gross domestic product] GDP that ranges from 0.1 percent to 1.4 percent."[4]

Mobile broadband promises to help level the playing field, enabling whole new categories of users to experience broadband. Rural consumers beyond the reach of wired DSL and cable systems are but one example of the opportunity. Lower income subscribers unable to afford both fixed-line and wireless access services are another.

A 2008 Pew Research Report surveying Internet experts and specialists concluded that in 2020, "the mobile phone . . . [will be] the primary Internet connection and the only one for a majority of the people across the world."[5] There are 4 billion people around the world that use a cell phone. In contrast, less than a billion people have a personal computer.[6] Clearly, most people in underserved markets will first access the Internet and experience broadband over a mobile device.[7]

1.2.2 ENGINE FOR INNOVATION AND COMPETITION

Both the Internet and wireless have become synonymous with innovation and competition. They have spawned new industries and broken down traditional barriers to entry. Mobile broadband is driving growth and innovation to entirely new levels. Social networks are one illustration of how the Internet, now "mobilized," can deliver value to end users that could hardly have been envisioned a few years ago. Gaming is another example of an industry now squarely moving into the mobile domain. Yet these examples pale in comparison to the economic and commercial impact of enterprise applications, for which mobile broadband can drive additional significant efficiencies into countless industry sectors.

With the convergence of wireless and the Internet also comes dramatically enhanced competition, with companies from both domains scrambling to address the combined market. Such competition, fully

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[1] *Mobile Broadband Computing Services – Complement or Substitute for Fixed Broadband,* Pyramid Research (Mar. 2009), *excerpt available at* http://www.pyramidresearch.com/store/RPMOBILEBROADBAND0903.htm?sc=TL_RPMOBBB0903.

[2] *Mobile Broadband to be Worth $137 Billion by 2014,* Ovum Research (25 Mar. 2009), *available at* http://hspa.gsmworld.com/upload/news/files/08052009110918.pdf.

[3] *Mobile Broadband for the Masses,* McKinsey & Company *(Feb. 2009)* at p. 3 ("McKinsey Report"), *available at* http://hspa.gsmworld.com/upload/news/files/25032009113456.pdf.

[4] *Id.* at p. 4.

[5] *The Future of the Internet III.* Janna Quitney Anderson and Lee Rainie, Pew Internet and American Life Project (14 Dec. 2008) at p. 5, *available at* http://www.pewinternet.org/~/media//Files/Reports/2008/PIP_FutureInternet3.pdf.pdf.

[6] *Communities Dominate Brands: So Nokia is the World's Biggest Computer Maker in 2008*, Tomi T. Ahonen (26 Dec. 2008, cont'd 6 Jan 2009), *available at* http://communitiesdominate.blogs.com/brands/2008/12/so-nokia-is-wor.html.

[7] *See also Handset Sector – The Worst Year in History*, Macquarie Research (12 Feb. 2009) at p. 11 (referencing study by Execution Primary Research finding that telecoms bills (interned, fixed-line and mobile phone) along with personal care expenses, are the least discretionary items cut by consumers during economic downturns).

unleashed, stimulates creative forces that would otherwise remain dormant. One leading technologist has dubbed this the "application innovation effect" a virtuous cycle in which "capability encourages innovation" and more robust networks beget more attractive applications leading to greater attach rates and ultimately a richer environment for even further market growth.[8]

Spectrum is an essential raw material for existing and new entrants into the mobile broadband space, and is necessary "table stakes" in order to compete. Ever smarter spectrum approaches will be needed in order for mobile broadband services to thrive and for creativity to flourish in the sector.

1.2.3 COMPARISON WITH NARROWBAND

During the past decade, wireless service providers have added data services in addition to voice as integral parts of their offerings. For a long time now, in fact, wireless has been much more than just a voice service, and wireless data Average Revenue per User (ARPU) has grown at a faster rate than voice ARPU for the past several years.[9] While wireless web and data offerings have made great strides, wireless data speeds have lagged behind fixed-line approaches, like DSL and cable modems, due to bandwidth and technology constraints.

This difference between wireless and fixed-line data rates has two root causes: technology and spectrum. Earlier wireless technologies were voice-centric, with data added as an incremental or parallel offering. Voice is inherently a narrowband application compared to data services like web browsing, streaming video, interactive gaming and a myriad of others. In contrast, the vision for mobile broadband is one where every service, including voice, is offered as an application on a unitary network.

Earlier spectrum allocations were designed around the needs of voice services or voice with incremental data. However, data will in the not too distant future become the dominant traffic mode. As a result, spectrum planning and usage must account for the fact that mobile broadband services that customers find attractive will require both appropriately allocated and sufficiently large quantities of spectrum.

Spectrum planning and usage must also reflect the characteristics of the services and traffic. A case in point is Internet traffic, which as a general matter is highly asymmetrical in nature, with downlink traffic exceeding uplink traffic by average ratios of 5:1 in the near term – increasing to 6:1 in the future. Notably, these asymmetries are usually greater for consumer data than for business data.[10]

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[8] *Mobile Broadband Spectrum Demand*, Rysavy Research (Dec. 2008) at p. 9 ("Rysavy Report"), *available at* http://www.rysavy.com/Articles/2008_12_Rysavy_Spectrum_Demand.pdf.

[9] *See TelMeDaily*, UBS Investment Research (5 Jun. 2009) at p. 3 (noting "the dramatically weakening trends in voice service revenue globally, [and that] operators are increasingly pointing their strategic emphasis towards mobile data. This has been a trend already experienced in Europe/US and is now taking hold in emerging markets.")

[10] The WiMAX Forum projects traffic asymmetry of about 8:1 for consumer data versus 6:1 for business data by the year 2015. *See A Review of Spectrum Requirements for Mobile WiMAX Equipment to Support Wireless Personal Broadband Services*, WiMAX Forum (Sept 2007) at pp. 27, 31, *available at* http://www.wimaxforum.org/sites/wimaxforum.org/files/document_library/spectrum_requirements_for_mobile_wimax_sept2007.pdf ; *see also 3G Offered Traffic Characteristics Final Report,* UMTS Forum, Report No. 33, (November 2003), *available at* http://www.umts-forum.org/component/option,com_docman/task,cat_view/gid,228/Itemid,98/.

1.3 GLOBAL SPECTRUM ALLOCATIONS

In important respects, wireless service is truly boundless—radio frequency emissions do not respect geopolitical boundaries. In the context of the present task, this takes on additional meaning. Wireless service delivers best for consumers when the industry can leverage scale economies in the manufacturing of equipment and end user devices. To do so most effectively, it is vital that industry players have globally established technology standards designed for use with globally coordinated spectrum bands.

Historically, regional- or country-specific standards and spectrum allocations have not succeeded. For example, North America's IS-136 digital cellular standard ultimately gave way to GSM, even though both were based on TDMA techniques. And CDMA2000 has evidently failed to gain enduring global traction, ceding the floor to UMTS-HSPA and LTE in the most pervasive approaches to evolving beyond 3G technology.[11] In a similar fashion, harmonized spectrum allocations have proven most effective in delivering the scale and scope economies needed to produce low cost consumer devices.[12]

A brief overview of global spectrum allocations for 3GPP based technologies follows. Subsequently, several examples – beginning with the U.S. AWS -III proceeding – are presented in orde r to illustrate some of the key challenges presented for optimal spectrum utilization when allocations differ either on a country- or region-specific basis.

1.3.1 OVERVIEW OF CURRENT 3GPP ALLOCATIONS

The Third Generation Partnership Project (3GPP) is a collaborative agreement established in 1998, comprised of six regional telecommunications standards bodies. 3GPP's mandate is to produce technical specifications (organized into documents commonly referred to as "Releases") and other reports for the development of 3G mobile systems based on evolved GSM core networks and radio access technologies.

As depicted in the following charts, 3GPP has fostered global harmonization of 3G and evolving 3G services by framing its Releases in accordance with the frequency bands most commonly used across the globe for commercial mobile services. Figure 1 lists commonly used FDD spectrum bands; Figure 2, common TDD bands. The second column in each figure identifies the countries and regions of the world in which these bands have been allocated for commercial mobile services.

[11] *See DoCoMo Shells Out on LTE*, Light Reading Asia (9 Jun. 2009), *available at* http://www.lightreading.com/document.asp?doc_id=177740 (reporting that NTT DoCoMO plans to launch LTE in 2H2010, a timeframe similar to Verizon Wireless, TeliaSonera, and China Mobile, the latter with the TD version of LTE). *See also NGMN Alliance and TD Industry Association Initiate Cooperation on Next Generation Mobile Networks,* News Release (4 Jun. 2009), *available at* http://www.ngmn.org/nc/news/partnernews/newssingle0/article/ngmn-alliance-and-td-industry-association-initiate-cooperation-on-next-generation-mobile-networks.html?tx_ttnews%5BbackPid%5D=3&cHash=016288ba43 (announcing cooperation agreement between the two organizations to promote TD-LTE worldwide and ensure development of convergent standard for FDD- and TDD-based next generation mobile networks).

[12] *See Written Submission of Verizon Wireless to House Energy & Commerce Committee* (21 May 2009) at pp. 17-18, *available at* http://energycommerce.house.gov/Press_111/20090507/testimony_verizon.pdf ("Global harmonization of spectrum allocations can lead to significant public benefits, including lower equipment cost, more rapid deployment, and greater interoperability of advanced wireless systems worldwide").

Release	Region	Operating band [4]	Band name	Total spectrum	Uplink [MHz]	Downlink [MHz]
R'99→		Band 1	2.1 GHz	2x60 MHz	1920-1980	2110-2170
Rel-4	2	Band 2	1900 MHz	2x60 MHz	1850-1910	1930-1990
Rel-5		Band 3	1800 MHz	2x75 MHz	1710-1785	1805-1880
Rel-6		Band 4	1.7/2.1 GHz	2x45 MHz	1710-1755	2110-2155
	1	Band 5	850 MHz	2x25 MHz	824-849	869-894
	Band 6 not applicable →	Band 6	800 MHz	2x10 MHz	830-840	875-885
Rel-7		Band 7	2.6 GHz	2x70 MHz	2500-2570	2620-2690
		Band 8	900 MHz	2x35 MHz	880-915	925-960
		Band 9	1700 MHz	2x35 MHz	1749.9-1784.9	1844.9-1879.9
	3	Band 10	Ext 1.7/2.1MHz	2x60 MHz	1710-1770	2110-2170
Rel-8	Band 11 to → change	Band 11	1500 MHz lower	2x25 MHz	1427.9 - 1452.9	1475.9 - 1500.9
		Band 12	Lower 700 MHz	2x18 MHz	698-716	728-746
		Band 13	Upper 700 MHz	2x10 MHz	777-787	746-756
		Band 14	Upper 700 MHz, public safety/private	2x10 MHz	788-798	758-768
		Band 17	Lower 700 MHz, AT&T blocks B&C	2x12 MHz	704-716	734-746

Notes:

(1) Parts of S. America (ITU Region 2) , Parts of Asia (ITU Region 3)
(2)ITU Region 2
(3)N. America excluding USA

Figure 1. 3GPP FDD Spectrum Bands (Source: 3GPP TS 36.104)

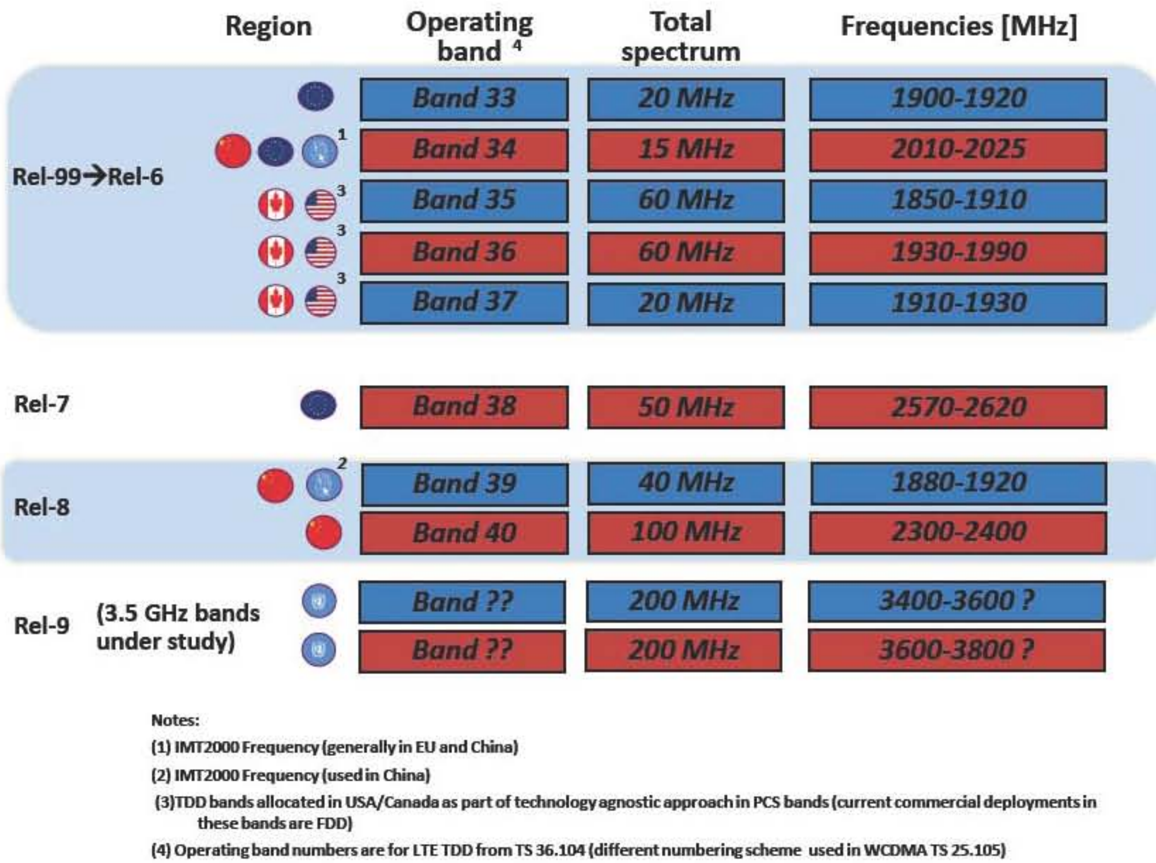

Figure 2. 3GPP TDD Spectrum Bands (Source 3GPP TS 36.104)

3GPP Release 5 includes the specifications commonly referred to as HSDPA; Release 6 HSUPA; Release 7 HSPA and HSPA+; and Release 8 HSPA+ and initial LTE specifications. These Releases provide participants in the mobile value chain – including chipset manufacturers, software developers, handset and infrastructure vendors, service providers and others – with an indispensable framework to realize scale economies that redound to the benefit of consumers across the globe. Deviations from this framework invariably result in challenges to delivering the compelling mobile services to consumers in a cost-effective manner. The following section provides several illustrations of currently divergent, or potentially divergent, spectrum allocations.

1.3.1.1 ILLUSTRATIONS OF CURRENT SPECTRUM ALLOCATION CHALLENGES

US AWS-III PROCEEDING

The FCC has an active proceeding to determine service rules and requirements for use of the AWS-II and AWS-III bands. The AWS-III band is adjacent to AWS-I, as shown in the band plan below. The AWS-III allocation consists of 20 MHz unpaired spectrum at 2155-2175 MHz. The AWS-II band consists of the H Block (1915-1920/1995-2000 MHz) and J Block (2020-2025/2175-2180 MHz). To minimize fragmentation, a number of parties have proposed pairing the AWS-III band with the downlink portion of the 2x5 MHz J Block, which would increase the upper bound to 2180 MHz.

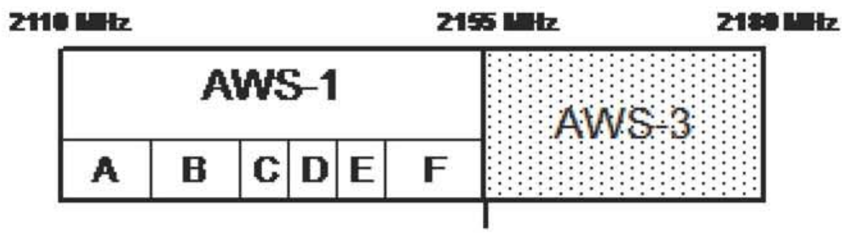

Figure 3. US AWS-I Downlink and AWS-III Bands

The FCC has proposed to allow Time Division Duplex (TDD) operation in AWS-III immediately adjacent to the AWS-I F Block downlink. Operation of TDD next to FDD is a widely known interference problem.[13] European regulators, for example, have allowed only "restricted" TDD next to FDD, limiting adjacent band TDD to tiny picocells using much lower transmit power, in the context of the 2.6 GHz band, as described further below. In contrast, the FCC proposes targeting comparatively "unrestricted" AWS-III TDD directly adjacent to AWS-I FDD. This rulemaking remains open at the present time.

Globally, the AWS-III spectrum has been identified by ITU for downlink-only operations, so the U.S. allocation for TDD (with its uplink and downlink usage) would be divergent. Such an un-harmonized allocation would likely limit the vendor ecosystem for AWS-I and AWS-III, compared to PCS or 700 MHz. In addition, this also has the potential to reduce the economies of scale for handsets used in the U.S. since most of the world uses spectrum between 2110-2180 MHz as FDD downlink. In particular, unique handset filters would need to be engineered for these bands that would address the particular RF environment that would be anticipated across 2110-2180 MHz in the U.S. should the FCC adopt this proposal.

CEPT 2.6 GHZ BAND PLAN

Several countries in Europe are moving toward adopting flexible allocations that would permit UMT Terrestrial Radio Access (UTRA) FDD systems to coexist with TDD systems in the 2500-2690 MHz band

[13] *See Public Policy Annual Review 2009*, GSM Association (March 2009) at p. 19, *available at* http://gsmworld.com/documents/GSMA_Public_Policy_Annual_Review_09.pdf?PUPOL=ANREV (noting that "[S]ome technologies (such as FDD and TDD) cause very serious interference problems and can lead to the requirement for large swaths of spectrum to be sterilized. To prevent such interference problems requires that the spectrum property right used in [spectrum liberalization efforts] is well defined and easily enforceable.").

established at WRC-2000. The European Commission (EC) has instructed National Regulatory Administrations (NRAs) to recognize that accommodating TDD and FDD in the 2.6 GHz band requires restricted blocks (i.e., reduced power and filtering).[14] An EC technical report released in April 2008 further describes the rationale for this requirement:

> To achieve compatibility a separation of 5 MHz is needed between the edges of spectrum blocks used for unrestricted TDD (time division duplex) and FDD operation (frequency division duplex) or in the case of two unsynchronized networks operating in TDD mode. Such separation should be achieved by either leaving these 5 MHz blocks unused as guard blocks; or through usage that complies with parameters of the restricted BEM when adjacent to an FDD (uplink) or between two TDD blocks; or through usage that complies with parameters of either restricted or unrestricted BEMs when adjacent to an FDD (downlink) block. Any usage of a 5 MHz guard block is subject to an increased risk of interference.[15]

CEPT Report 19, first released in December 2007, established the minimum technical requirements for this accommodation. [16] The following spectrum block diagram taken from that report depicts the basic safeguards for implementing the CEPT band plan.

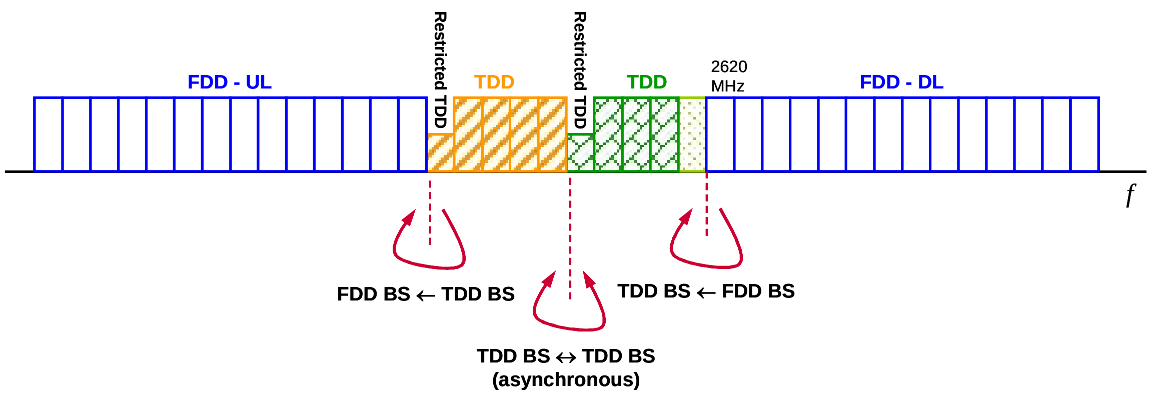

Figure 4. CEPT 2.6 GHz Band Plan Depicting Safeguards Required for Adjacent FDD/TDD Operation

In the U.K., the NRA (Ofcom) has yet to release final regulations governing the 2.6GHz band. Its most recently proposed plan, however, would reflect the need for guard channels between the adjacent technologies as recognized by CEPT. However, Ofcom's proposed band plan allows for an increase in the amount of unpaired spectrum at the top end of the band relative to the CEPT plan, which has the

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[14] *See Commission Decision of 13 June 2008 on the Harmonization of the 2500-2690 MHz Frequency Band for Terrestrial Systems Capable of Providing Electronic Communications Services in the Community*, 2008/477/EC (24 Jun. 2008) ("EC 2008 2.6 GHz Harmonization Decision"), *available at* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:163:0037:0041:EN:PDF.
[15] *See Final Draft Decision on 2500-2690 MHz,* EC Radio Spectrum Committee (23 Apr. 2008) at para. 8, *available at* http://circa.europa.eu/Public/irc/infso/radiospectrum/library?l=/public_documents_2008/rsc23_april_2008/rscom08-02_2500-2690/_EN_1.0_&a=d.
[16] *See Report from CEPT to the European Commission in Response to the Mandate to Develop Least Restrictive Technical Conditions for Frequency Bands Addressed in the Context of WAPECS* (21 Dec. 2007) at p. 37 ("CEPT Report 19"), *available at* http://www.erodocdb.dk/Docs/doc98/official/Word/CEPTREP019.DOC.

advantage of preserving the 120 MHz duplex spacing for the paired spectrum but the disadvantage that it could require an extra guard channel. This is reflected in Figures 5 and 6 below.[17]

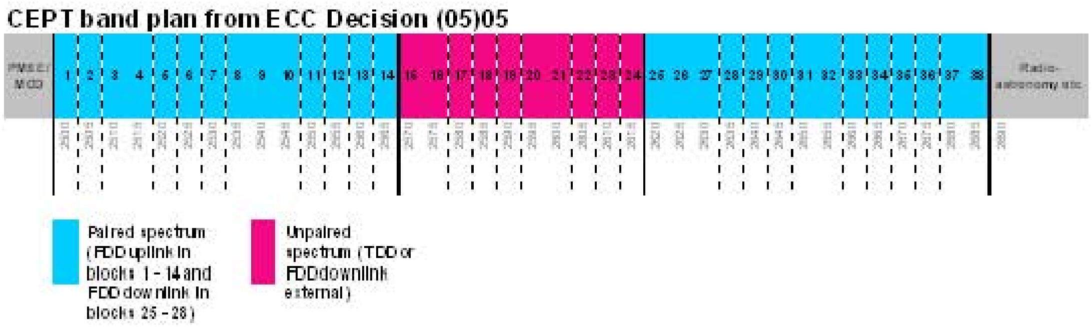

Figure 5. CEPT Band Plan from ECC Decision (05)05 with Predetermined Amounts of Paired and Unpaired Spectrum

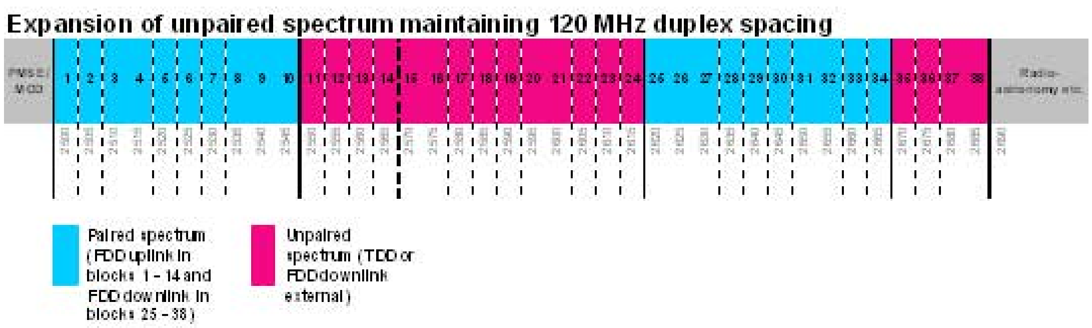

Figure 6. Ofcom Illustration of Expansion Amount of Unpaired Spectrum at Top End of 2.6 GHz Band Relative to the CEPT Band Plan (Duplex Spacing of 120 MHz Maintained)

At the same time, Ofcom has undertaken extensive technical investigations in preparation for eventual release of this spectrum. As early as November 2006, Mason Research completed a study commissioned by Ofcom that concluded that:

> The results of the worst-case analysis demonstrated that FDD/TDD, and TDD/TDD, co-existence is not feasible at either 10 or 15 MHz offset without suitable interference mitigation. At 10 MHz and 15 MHz offset, the separation distance between base stations in the BS-BS interference scenario is, again, in excess of 1 km, with excessive interference also occurring between mobiles (though less than the 5 MHz offset case). This suggests that operation of FDD and TDD systems

[17] *See Award of Available Spectrum: 2500-2690 MHz, 2010-2025 MHz and 2290-2300 MHz*, Consultation (11 Dec. 2006) at pp. 6-7, *available at http://www.ofcom.org.uk/consult/condocs/2ghzawards/2ghzawards.pdf; Notice of Ofcom's Proposal to Make Regulations in Connection with the Award of 2500-2690 MHz and 2010-2025,* Consultation *(*4 Apr. 2008) at pp. 34-36, *available at* http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/notice.pdf.

in adjacent frequency blocks in the same frequency band is not feasible without consideration of suitable interference mitigation techniques.[18]

Further on, the study notes that "the results of our analysis suggest that interference will be noticeable when the distance between mobiles is less than 10 meters."[19]

In April 2008, Ofcom published the final results of its investigations on the impact of interference from TDD terminals to FDD terminals in the 2.6 GHz band.[20] Ofcom confirmed the need for restricted blocks to mitigate inter-system interference, as depicted in an illustrative block diagram reproduced below.

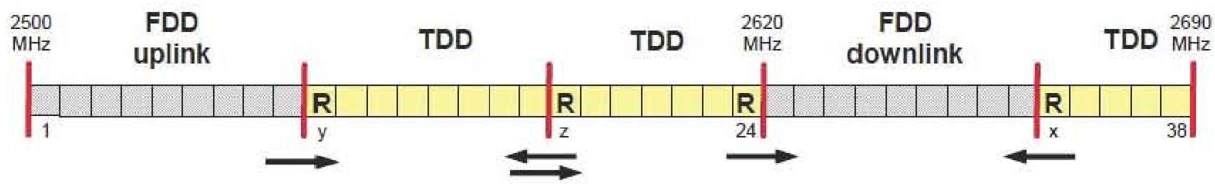

Figure 7. Ofcom Illustration of Restricted Blocks for Example of a Specific Award Outcome (Arrows Indicate Direction of Potential Terminal-to-Terminal Interference; Restricted Blocks Marked with "R")

Ofcom found that "[al]though the restricted blocks are primarily intended to mitigate base-to-base interference, they also have important implications with respect to terminal-to-terminal interference."

Ofcom noted risks of "significant" first adjacent-block interference from TDD terminal stations towards FDD terminal stations existed where the TDD terminal stations are served by high power macro-cellular base stations, and where there is a high density of TDD terminal operating in the spatial vicinity of the FDD terminal stations. Ofcom goes on to note that the restricted blocks address the important, collateral scenario of TDD terminal to FDD terminal interference. Interference risks would be minimized if TDD terminals are:

> [S]erved by low power pico-cellular base stations. This is consistent with the case of TDD terminal stations that operate in the restricted blocks immediately below and above the FDD downlink spectrum (i.e., block #24 and block "x" in Figure 7). In other words, the restrictions on in-block EIRP imposed on TDD base stations in the aforementioned two restricted blocks remove the circumstances in which FDD terminal stations might suffer from interference caused by TDD terminal stations.[21]

[18] *2500-2690MHz, 2010-2025MHz and 2290-2302MHZ Spectrum Awards – Engineering Study (Phase 2),* prepared for Ofcom by Mason Communications Ltd, at p. 7, *available at* http://www.ofcom.org.uk/consult/condocs/2ghzawards/masonresearch.pdf.

[19] *Id.*

[20] *On the Impact of Interference from TDD Terminal Stations to FDD Terminal Stations in the 2.6 GHz Band*, Statement (21 Apr. 2008) at p.18 ("Ofcom 2008 2.6 GHz FDD/TDD Technical Report")*, available at* http://www.ofcom.org.uk/consult/condocs/2ghzregsnotice/tech.pdf.

[21] *Id.*

Recently, the U.K. has proposed a wide ranging overhaul of its plan for allocating spectrum for mobile broadband services. Released May 12, 2009 by the U.K. Ministry of Culture, Media & Sports, the *Report of the Independent Spectrum Broker*,[22] posits that the UK view collectively the future of all the blocks of spectrum suitable for two-way mobile communications, including the 2.6 GHz band (as well as 800 MHz, 900/1800 MHz and 2.1 GHz). The Independent Spectrum Broker (ISB) Report explains that:

> The rationale for an integrated approach derives largely from the fact that NGM [next generation mobile] technologies require large blocks of spectrum (either operated by a single party or multiple parties working collectively with contiguous spectrum) for their potential to be fully realised – blocks of 2 x 10 or (preferably) 2 x 20 MHz – and that truly national high capacity networks require spectrum at both low and high frequencies. Addressing these requirements in an integrated way, if that can be achieved quickly, should give operators greater certainty over their future spectrum holdings whilst continuing to support a competitive market outcome.[23]

The specific 2.6 GHz proposals would provide, according to the report, for: (1) a separate auction of the TDD 2.6 GHz spectrum suitable for WiMAX services before the end of 2009;[24] and (2) coordinating the upcoming FDD suitable auctions at 2.6 GHz and 800 MHz to allow existing and new operators to build spectrum holdings in an integrated, strategic fashion.

The U.K. incorporated the majority of the proposals in the ISB Report in its *Digital Britain Final Report* released in June 2009.[25] Shortly thereafter, Ofcom announced that it was "no longer appropriate to rely on its decision of 4 April 2008 to hold the award of the 2.6 GHz band as soon as possible" and consequently withdrew that determination on timing. [26]

The ISB Report does not suggest changes to the 2.6 GHZ band plan that Ofcom has proposed. More importantly for purposes of this document, the ISB Report respects the technical conclusions previously made by Ofcom as the result of investigations spanning over several years. As such, the proposals are respectful of the principle – as exemplified recently by the FCC in its 700 MHz auction – that identification of technical restrictions prior to auction, while promoting broader access to spectrum by various technologies, is a hallmark of sound spectrum policy.[27]

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[22] *See Report from the Independent Spectrum Broker: Findings and Policy Proposals*, Final Report (12 May 2009), *available at* http://www.culture.gov.uk/images/publications/ISB_final_report.pdf.

[23] *Id.* at p. 6.

[24] *See China's Potential Pioneering Role in 4G,* New Street Research (8 May 2009) at p. 13 (noting that many operators globally have unused TDD spectrum and that significant quantities of TDD spectrum are to be auctioned shortly, and while unpaired spectrum prices have been significantly lower than paired – as much as 80 to 90 percent, or attracting no bids at all – this dynamic may change if China Mobile meaningfully deploys TDD LTE, as New Street Research anticipates).

[25] *Digital Britain – Final Report*, Department for Culture, Media and Sport and Department for Business, Innovation and Skills (16 Jun. 2009), *available at* http://www.culture.gov.uk/images/publications/digitalbritain-finalreport-jun09.pdf.

[26] *Ofcom Update on the 2.6 GHz Award* (23 Jun. 2009), *available at* http://www.ofcom.org.uk/radiocomms/spectrumawards/awardspending/award_2010/Update26GHz230609.pdf.

[27] *See Service Rules for Advanced Wireless Services in 2155-2175 MHz Band*, Comments of AT&T Inc., WT Docket 07-195 (25 July 2008) at pp. 28-34, *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520035686 (describing FCC decisions on important elements of band plans and technical rules for 700 MHz (as well as PCS) auctions that effectively gave bidders sufficient information to account for these factors in their bidding strategies).

DIGITAL DIVIDEND SPECTRUM

The Digital Dividend refers to the reallocation of significant amounts of spectrum as a result of the switchover from analog to digital TV, a phenomenon occurring across the globe. Historically, analog TV operates in the UHF band between 470-862 MHz.

The analog to digital switchover will free a substantial amount of spectrum for new services, including digital television and mobile broadband.

Mobile services will need at least 100 MHz of this spectrum for mobile broadband. The results of WRC 07 incorporate this vision, as well as the need to promote harmonization of these bands, as reflected in the following figure:

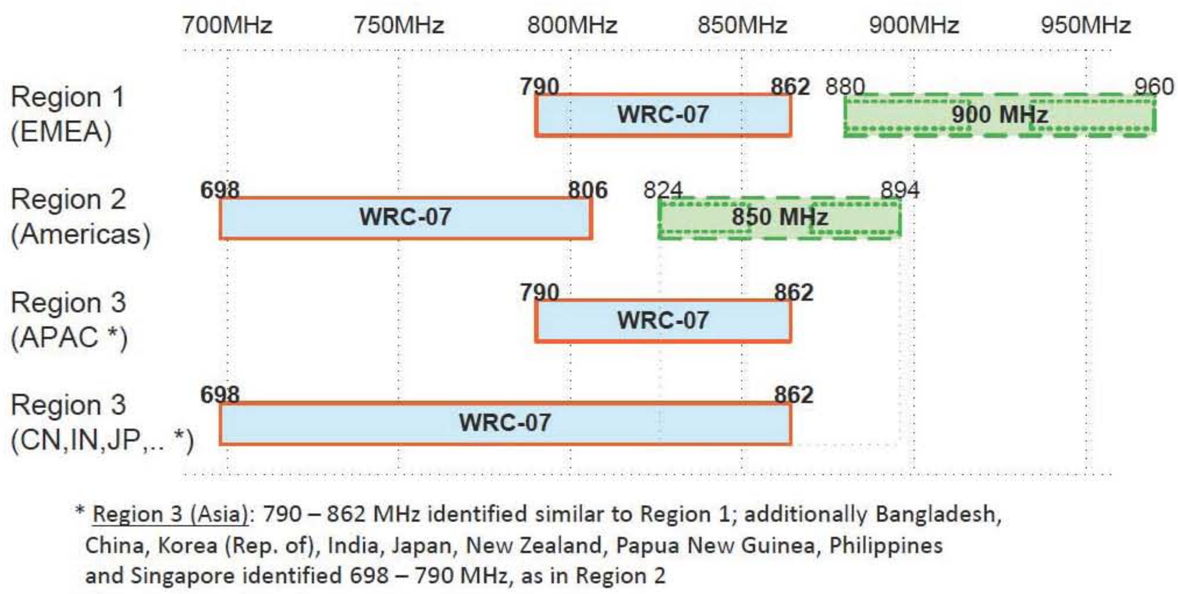

Figure 8. Digital Dividend Spectrum Identified by WRC 2007 for Mobile Broadband

As is planned, there is no one globally harmonized Digital Dividend spectrum band. Further, the APAC countries have the flexibility to adopt the Region 1 or Region 2 plans. The important task of promoting harmonization and aligning band plans as far as possible with WRC-07 agreement, in order to realize the benefits of harmonization for their citizens, now falls to policymakers to accomplish.[28]

[28] *See e.g. GSMA Applauds Actions to Establish a Harmonised Approach to Spectrum Allocation*, Cellular-News (9 June 2009), *available at* http://www.cellular-news.com/story/37933.php?source=rss (reporting on recent Baltic Sea Summit organized by Finnish Ministry of Communication involving 9 countries (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden), devoted to developing a unified approach to allocation of Digital Dividend spectrum in the region, citing among other summit objectives the need to develop coordination procedures to overcome interference with legacy aeronautical systems and mediate between military and broadcast use of digital dividend spectrum at a regional level).

In fact, the EC recently launched a consultation on Digital Dividend spectrum. Noting that importance of taking prompt action "to prevent the emergence of fragmented national legacy situations" that would stymie the development of future equipment and services in the 800 MHz band, the consultation proposes that the EC undertake two urgent actions by autumn of 2009: (1) Member States that have not completed the digital switchover would be requested to confirm switch off of analogue TV under national law by 1 January 2012; and (2) the EC would draft a Commission decision, for regulatory opinion in the autumn of 2009 and formal adoption at the beginning of 2010, on technical harmonization measures for transitioning the 790-862 MHz band to non-broadcast uses.[29]

2. SPECTRUM POLICY GOALS

The establishment of spectrum policy goals requires a careful (and at times difficult) reconciliation of many interests, against the backdrop of increasing demand for spectrum assets and continued scarcity in the supply of those assets. Further, the technologies underlying mobile broadband are evolving at a dramatic pace. Therefore, policy makers and stakeholders confront considerable challenges in crafting policies which maximize the use of these resources for the public good. Sections 2.1, 2.2, 2.3, 2.4 and 2.5 below provide an overview of widely held tenets considered fundamental for sound spectrum policy.

2.1 SPECTRUM HARMONIZATION

In a very real and practical sense, it is the lack of harmonization that compels the search for the technological approaches to be discussed later in this document. Non-standard allocations, in other words, drive the need to develop alternative technological approaches and technical safeguards for maximizing available spectrum usage. Failure to do so relegates certain bands to fragmented status, where they in effect become isolated islands, in comparison to the allocation schemes governing spectrum in other regions of the world. Thus, harmonization is one of, if the not the chief, goal of spectrum policy.

The wireless infrastructure and device marketplaces are relatively mature industries, and consequently presuppose high volumes to drive down costs, yielding attractive end user prices for wireless devices, products and services. Unfortunately, radio equipment is not like digital or computer equipment which can be reconfigured comparatively easily to account for differences, such as language, from one country to another. Radio equipment, including handsets or base stations, requires hardware specific to the frequency band of operation. While certain technologies hold promise to bring a degree of agility to wireless equipment in the future, the fact remains that today and in the immediate term, band-specific hardware (including filters, duplexers, and antennas) must be incorporated into products at the time of manufacture.

If spectrum allocations are not harmonized, then different products must be designed and manufactured for different countries or regions. By definition, such products are fabricated in lower volumes and hence

[29] *Transforming the Digital Dividend Opportunity into Social Benefits and Economic Growth in Europe*, EC Consultation Document (10 Jul. 2009) at pp. 9-10 , *available at* http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/consultations/2009_digital dividend/2009_0710_0904_digitaldividendconsultation.pdf. At the present time, Austria, the Czech Republic, Finland, France, Germany, Spain, Sweden, the Netherlands and the United Kingdom have begun consideration of how to open the 800 MHz band for innovative uses such as mobile broadband.

with higher bills of materials and manufacturing costs. This translates into significant cost penalties on the lower volume products delivered to countries or regions that have chosen not to align their spectrum with global allocations

U.K. research firm RTT has undertaken several studies related to the impact on spectrum harmonization on handset costs. In particular, a 2007 RTT study examined the impact of non-standard band allocations on the cost and performance of cellular handsets and by implication, the impact of RF device and design trends on spectrum allocation policy. [30] RTT concluded that non recurring engineering costs increase as the level of integration needed to accommodate non-standard spectrum bands increases. These costs are not volume dependent but, importantly, their recovery is – and across significant market volume. RTT further noted that present industry engineering resource constraints introduce generally underestimated opportunity cost multipliers that significantly increase the real cost of cellular handsets intended for non standard spectrum. Figure 9, derived from RTT's analysis, illustrates the inverse relationship between the price needed to recoup non-recurring engineering costs and market volume of units produced:

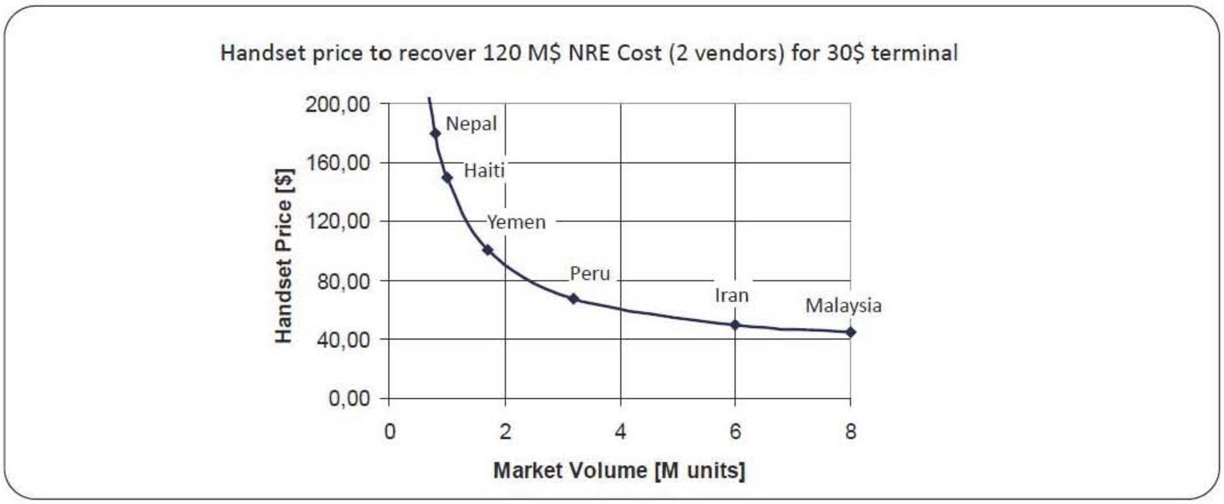

Figure 9. Low Cost Handset Price Reductions as Market Volumes Increase (Source: RTT)

In addition to economic costs, roaming is another critical benefit stemming from harmonization. The mobility inherent in wireless service has made global roaming a mandatory offering for most service providers. If spectrum bands are not aligned around the globe, then global roaming can be difficult or impossible to achieve. Cost and size constraints place limits on the number of bands and technologies that typical small and low-cost consumer wireless devices can incorporate. This means that support for fragmented spectrum allocations must often be sacrificed in favor of the more common global bands. Harmonization, furthermore, aids countries that share borders in managing the potential for cross border interference.

[30] *RF Cost Economics for Handsets*, RTT (5 Sept. 2007), *white paper available for download at* http://www.rttonline.com/home_frame.htm

2.2 TECHNOLOGY FACILITATION

The mobile and Internet industries have repeatedly demonstrated the tremendous value in allowing the market to sort out winners and losers. Technologies continually evolve and leapfrog one another, and today's underdog can easily emerge as tomorrow's front runner. Technology Facilitation, [31] allowing the market to sort out which technologies will prevail, is – and should continue to be – a fundamental policy tenet.

The clear lessons from the emergence of the Internet apply equally to mobile broadband. Once a technology backbone platform is in place, companies are apt to view the commercial significance of that platform in different ways. Business models are diverse and must necessarily adapt over time to recognize new realities. Flexibility allows companies to test different business models to see what works, as well as change business strategies as warranted.

Mobile broadband offerings are not about just voice services or just the wireless web. Like the fixed Internet, mobile broadband delivers high performance data transport services upon which a multitude of different applications can ride. This implies that spectrum policy should refrain from dictating which technology or service is offered in particular spectrum bands. Enabling flexibility is paramount for operators to have the opportunity to succeed in this rapidly evolving market. [32]

At the same time, it is important to clarify that facilitating different technologies does not mean that regulators should refrain from making any technology decisions in their spectrum allocations. The often-mentioned goal of "technology neutrality" merits pursuit, but only if properly interpreted.[33] Technology Facilitation comes closer to the mark, conveying the point that proper spectrum management is neutral as to the particular air interface technology (e.g. WiMAX, UMTS-HSPA, LTE) preferred by the licensee, and should facilitate entry by licensees regardless of the technology chose by the operator. However, this does not mean that regulators should abdicate the role of grouping "like" services together as required. Specifically, service providers need clarity – before spectrum is auctioned or otherwise assigned – as between spectrum designated for FDD (whether WiMAX- or UMTS-HSPA- or LTE-based FDD) and spectrum designated for TDD (again, regardless of air interface technology). Related to duplexing designations, there is also a concomitant need to define proper technical and operational parameters where different duplexing schemes may be employed in spectrum directly adjacent to each other, given the well understood interference concerns, as described above.

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[31] This concept is closely aligned with the concepts of "technology neutrality" and "spectrum flexibility" often used in policy discussions in various regions of the world. However, as explained below, important considerations need to be brought to greater relief regarding those concepts.

[32] In March 2009, Industry Canada announced a consultation on the transition to Broadband Radio Service (BRS) in the 2.6 GHz band, and on the criteria to be used in the issuance of BRS licenses to operators of qualified Multipoint Communication System (MCS) licenses and Multipoint Distribution Service (MDS) authorizations. Industry Canada noted that BRS licenses are often referred to as "flexible use" licenses in that they support a mix of services, including mobile, fixed and broadcasting (although in practice operations in this band have been fixed). The Department expressed its "commit[ment] to taking the necessary steps for the implementation of BRS in order to increase flexibility in service provision that would benefit Canadians by enabling the development of competitive high-speed mobile services." *Consultation on Transition to Broadband Radio Service (BRS) in the Band 2500-2690 MHz*, Notice No. DGRB-005-09 (6 March 2009) at p. 1, *available at* http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/dgrb-005-09-eng.pdf/$FILE/dgrb-005-09-eng.pdf

[33] *See* McKinsey Report at pp. 13-14 (describing the regulatory levers that will enable mass market mobile broadband to take root, including the primacy of spectrum availability, which includes "technology neutrality" to ensure innovation, but that neutrality "needs balancing against the desire to standardize.")

To illustrate, there is an initiative within the European Union to allow more flexible use of spectrum in its Member States. This initiative is called Wireless Access Policy for Electronic Communications Services (WAPECS). [34] WAPECS establishes similar and minimal technology conditions to allow the use of the spectrum for mobile, broadcasting and fixed services on a technology and service-neutral basis, subject to certain coexistence parameters to avoid harmful interference.

These coexistence concepts include both Block Edge Mask (BEM) and Restricted Blocks and are intended to facilitate coexistence between coordinated and uncoordinated services and technologies. In the CEPT 2.6 GHz band plan, as discussed previously, spectrum is organized with individual TDD and FDD allocations. The operators have the flexibility to implement technologies and services as the market dictates. In an uncoordinated spectrum environment, where allocations are not separate, there are cost and deployment consequences that may diminish the possibility to create economies of scale. Such an environment may also diminish device selection and possibly introduce demands on filter technology that could create market introduction delays.

2.3 BROADBAND DEPLOYMENT & ADOPTION

Spectrum policy should also strive more generally to stimulate broadband deployment and adoption. Mobile broadband is not just “more of the same” wireless voice or cell phone services. Spectrum policies which do not foster mobile broadband and enable it with sufficient spectrum resources could inadvertently restrict future offerings to “more of the same.” Such policies could also very well stifle efforts to bridge the “digital divide” in instances where mobile broadband can offer unique solutions, particularly in geographic areas and for particular demographic groups.

As discussed earlier, mobile broadband deployment and adoption can be an integral part of stimulating overall economic recovery and growth. The migration of the Internet to the mobile domain fuels further cycles of innovation and ecosystem creation, which bolsters healthy and sustainable economic growth. Thus, this goal indirectly serves to address the most pressing goal currently facing countries across the globe.

Demand for mobile broadband products and services are, as Cisco characterizes, “hard to overestimate.” Cisco forecasts that globally, mobile data traffic will double every year through 2013, increasing 66 times between 2008 and 2013. Moreover, according to Cisco, the mobile data traffic footprint of a single mobile subscriber in 2015 could very well be 450 times what it was in 2005, as the following depiction (Figure 10) from Cisco illustrates. [35]

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[34] *See* CEPT Report 19.
[35] *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update* (29 Jan. 2009), *available at* http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html. *See also The Road to LTE for GSM and UMTS Operators*, Analysys Mason (January 2009) (forecasting that total wireless network traffic generated from voice and data will increase ten-fold between the present and 2015 in developed regions and six fold in developing regions), *available at* http://hspa.gsmworld.com/upload/news/files/10032009144953.pdf.

Figure 10. Potential Growth in Data Traffic from a Single Mobile Subscriber (Source: Cisco)

Confronted with burgeoning demand, mobile network operators have three options for responding: build more cell sites; increase spectral efficiency of existing spectrum assets; and deploy more spectrum into their networks. Operators cannot pick and choose among these options, but must invoke all of them in the hunt for capacity.[36]

Cell site builds, however, reach a point of diminishing returns if the task consists solely of cell splitting an operator's existing frequencies. Investments in 2G and 3G technology enhancements have brought impressive spectral efficiency benefits for operators, but those benefits are constrained if channels of sufficient bandwidth are not available for deployment (putting aside the question of whether the spectrum is green field or whether legacy customers on older, incompatible technologies must be moved elsewhere). Thus, NRAs across the globe will play a critical role in allocating additional new spectrum to meet the needs of their residents. [37]

The amount of spectrum required by operators to meet the new broadband imperatives is a topic investigated by the International Telecommunication Union (ITU) in 2006. Specifically, the ITU undertook to determine how much spectrum would be needed for the case of a single network per country in the years 2010, 2015 and 2020. The table below summarizes the results of the ITU's analysis, which are broken down by "higher" or "lower" market development status compared to a single "global common market," as well as by Radio Access Technology Group (RATG). RATG 1 covers pre-IMT and IMT, as well as enhancements to IMT and RATG 2 is comprised of IMT-Advanced.

[36] *See* Rysavy Report at pp. 19-20.
[37] *See How Much More Spectrum Do We Need*, Saul Hansell, New York Times Bits Blog (4 Apr. 2009), *available at* http://bits.blogs.nytimes.com/2009/04/02/how-much-more-spectrum-do-we-need/ ("A number of factors are pushing up demand for wireless capacity, including the rapid adoption of smart phones, new applications and unlimited-use pricing plans.").

Market setting	Spectrum requirement for RATG 1			Spectrum requirement for RATG 2			Total spectrum requirement		
Year	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**
Higher market setting	**840**	**880**	**880**	**0**	**420**	**840**	**840**	**1 300**	**1 720**
Lower market setting	**760**	**800**	**800**	**0**	**500**	**480**	**760**	**1 300**	**1 280**

Figure 11. ITU Forecasted Spectrum Requirements (MHz)

In sum, the ITU concluded that total spectrum requirements would be 840 MHz by 2010, 1300 MHz by 2015 and 1720 MHz by the year 2020 (spectrum requirements would be higher for multiple networks, a scenario easily envisioned given the importance of competition in the market for mobile broadband service). Even for the situation in which a lower level of market development is assumed, the ITU projected total spectrum requirements of 760 MHz by 2010, 1300 MHz by 2015 and 1280 MHz by 2020.[38]

Extrapolating from the ITU's forecast, the following year the NGMN Alliance (a coalition of operators, industry partners, and academic advisors focused on providing a vision for technology evolution beyond 3G) determined what the net spectrum requirement would be, based on existing allocations, in each of the three ITU regions. The following chart (Figure 12) presents the NGMN Alliance's findings, which, in sum, determined that, depending on region, between 500 MHz and 1 GHz would be needed.[39]

		Region 1		Region 2		Region 3	
Market Setting	Predicted total (MHz)	Identified (MHz)	Net additional (MHz)	Identified (MHz)	Net additional (MHz)	Identified (MHz)	Net additional (MHz)
Low	1 280	693	587	723	557	749	531
High	1 720	693	1 027	723	997	749	971

Figure 12. NGMN Alliance Extrapolation of ITU-R M.2078 to Provide Net Spectrum Requirements by ITU Region for the Year 2020

While circumstances in individual countries will certainly vary, what is beyond peradventure is that significant additional spectrum will need to be allocated in order to address the needs of consumers

[38] *Estimated Spectrum Bandwidth Requirements for the Future Development of IMT-2000 and IMT-Advanced*, Report ITU-R M.2078 (2006).
[39] *Spectrum Requirements for the Next Generation of Mobile Networks,* NGMN Alliance (20 Jun. 2007) at p. 22, *available at* http://www.ngmn.org/uploads/media/Spectrum_Requirements_for_the_Next_Generation_of_Mobile_Networks.pdf.

around the world. Given the lengthy lead times needed to identify spectrum, and in particular regionally or globally harmonized spectrum, NRAs must begin the process of securing the necessary spectrum in earnest.

2.4 SPECTRAL EFFICIENCY

Wireless transport of information is fundamentally different than fixed-line transport. The transport of data over fixed-line fiber optic cables provides virtually limitless capacity for high data rates. Coaxial or other wire cables do not provide infinite bandwidth, but they do support enormous data capacities compared to typical wireless spectrum blocks. In contrast to fixed-line scenarios, spectrum is an extremely limiting resource with many competing allocations. Because spectrum is so limited, policies that maximize spectrum efficiency (i.e. the data rate transported in a given bandwidth, typically measured in bits/second per Hertz) and access are paramount. CEPT's 2.6 GHz band plan, for example, makes allowance for operators to realize the efficiency gains of carrier aggregation (as discussed below), by allowing unpaired channels to be used either for TDD or for FDD downlink.

Computing and the Internet serve as prime illustrations of the fact that for consumers, "build it and they will come" holds true. Consumers have discovered new ways to use processing power (microprocessors with ever increasing clock speeds), memory (from KB to MB to several GBs and soon beyond), and hard disk space (from a few MB to hundreds of GB to terabytes). The same is true of Internet speeds, with past dial-up connections of 9.6 kbps giving way to 56 kbps, and then to tens of Mbps and now hundreds of Mbps pipes emerging. Mobile broadband is no exception to this rule.

One important lesson for spectrum policy that can be derived from the success of the Internet is that policy should be formulated in an open and transparent method that is fair and evenhanded in its treatment for all spectrum holders. Furthermore, to the extent tensions arise, policy makers should craft rules to resolve such tensions bolstered by hard empirical data and technical data forged in the fire of the marketplace.

2.5 PREDICTABLE SPECTRUM VALUATION

The key to ensuring maximum return on spectrum assets at auction is the ability of the potential bidders to model the value of the spectrum in a transparent and timely fashion. Risk is a part of any business endeavor and companies anticipate the need to continually manage for it. However, they can only do so if risks are clearly identified prior to computing valuations.

Uncertainty and ambiguity are the enemies of this valuation process. If companies are unclear about how a particular band might be allocated, what interference and other technical rules they might face, or how policies might change in the future, then they instinctively will tend to value the spectrum conservatively and to consider possible uses narrowly. When policy makers provide clear guidance, risks are minimized, leading to heightened interest and the broadest usage considerations. This, in turn, drives up valuation of the spectrum, corresponding to its greatest valued uses.

3. CURRENT APPROACHES TO ADDRESSING FRAGMENTED SPECTRUM CHALLENGES

3.1 ASYMMETRIC PAIRING & DUAL CARRIER/DUAL BAND AGGREGATION

There is considerable promise for mobile broadband services in the option to deploy frequency division duplex with asymmetrically paired spectrum channels, resulting in more downlink than uplink bandwidth. Asymmetric pairing facilitates the deployment of robust, two-way mobile broadband services. Such pairing matches well with the demand for broadband capability, which experience indicates is predominately focused on downloads. For example, with 25 MHz of downlink spectrum, a provider could offer average download speeds of up to 35 Mbps per sector, based on modeling using emerging next generation technologies such as LTE in an FDD configuration without multi-antenna signal processing. A 5 MHz asymmetrically paired uplink would provide users with an average upload speeds of up to 4 Mbps per sector, sufficient for uploading videos and other bandwidth intensive content.

Asymmetric pairing makes sense for broadband services generally because most Internet traffic is asymmetric, with greater traffic in the downstream direction. In fact, traffic asymmetry can be even greater due to local and temporal variations. The traffic generated by individual users can be highly asymmetric in either direction. Some kinds of applications (e.g. web browsing) would lead to significant asymmetry, with more downlink traffic than uplink traffic in a mobile network. Others are typically symmetric (e.g. voice and video telephony). Still others may be asymmetric in the opposite direction (e.g. uploading photographs). The general trend for aggregated traffic, however, is increasingly asymmetric in the downlink.

3GPP has been actively engaged in work to enable asymmetric pairing for the UMTS-HSPA family of technologies. In particular, Dual Carrier HSDPA (DC-HSDPA) is a feature set that combines two adjacent radio carriers in the downlink (while maintaining one channel in the uplink) that would effectively double theoretical user downlink data rates.

Notably, the capacity benefits of carrier aggregation for HSDPA scale at more than a linear rate. As the illustration below depicts, one additional 5 MHz DL carrier can result in 8x the capacity of a single 5 MHz DL carrier (using 3.6 Mbps HSDPA); an additional 5 MHz DL carrier results in 24x the capacity versus the baseline 5 MHz carrier.[40]

[40] *Mobile Broadband: A Silver Lining Amongst All the Clouds*, Deutsche Bank (14 Oct. 2008) at p. 19.

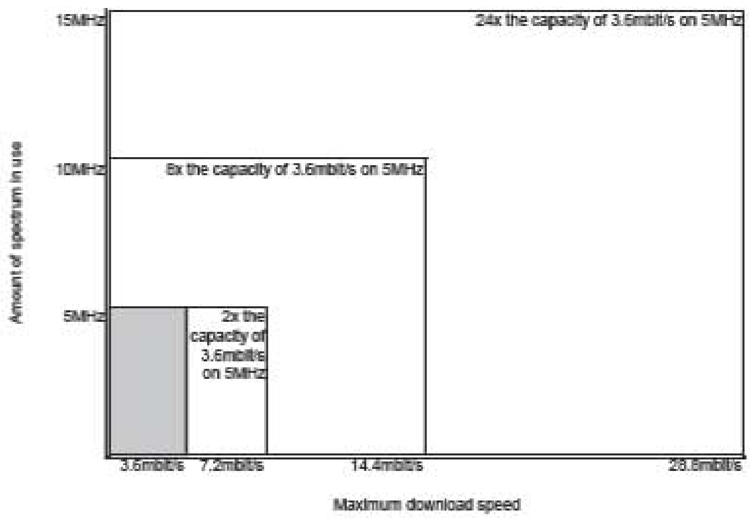


Figure 13. Benefits of Carrier Aggregation for HSDPA Scale More than Linearly (Source: Deutsche Bank)

The multiplicative rate of capacity gains results from scheduling efficiencies involved in employing multiple carriers.[41]

3.1.1 3GPP RELEASE 99 THROUGH RELEASE 7

3GPP Release 7, which established the technical specifications for HSPA+, continued to build on the common framework of paired 2x5 MHz carriers, with 5 MHz dedicated to the uplink and 5 MHz for the downlink, and a fixed duplex distance between the carriers. This is depicted in Figure 14.

[41] *See HSPA Performance and Evolution: A Practical Perspective,* Pablo Tapia *et al*. (John Wiley & Sons Ltd., 2009) at p. 200 (explaining that the gains will be more than adding independent multi-carriers because they benefit from additional trunking efficiencies associated with the larger "channel pool").

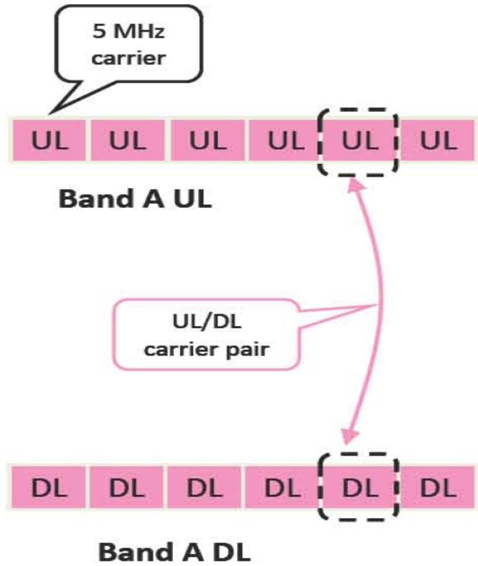


Figure 14. WCDMA/HSDPA UL& DL Carrier Pairing in Single Carrier Operation

3.1.2 3GPP RELEASE 8 INTRODUCED DUAL-CARRIER HSDPA

In December 2008, 3GPP froze Release 8 specifications. Release 8 introduced support for DC-HSDPA. However, the specifications permit only two DL carriers (5 MHz per carrier) adjacent to each other and in the same frequency band, with one of the DL carriers preserving the fixed duplex spacing from the UL carrier. This is depicted in Figure 15.

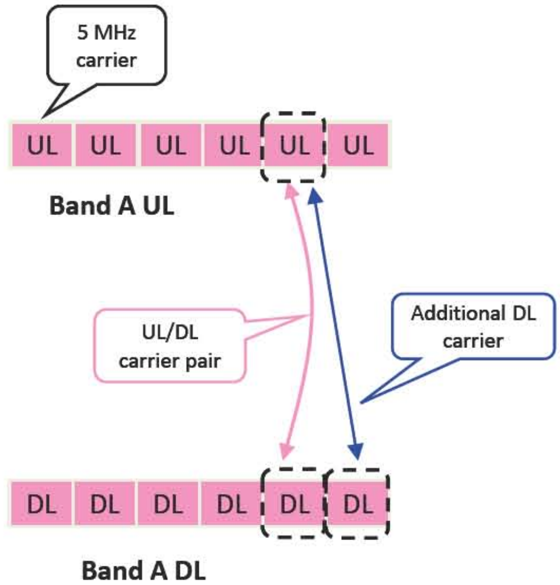


Figure 15. DC HSDPA on Adjacent Carriers: 1 UL Carrier, 2 DL Carriers (3GPP Release 8)

3.1.3 3GPP RELEASE 9 WOULD INTRODUCE DUAL-CARRIER HSDPA/HSUPA

The development of technical specifications that permit additional resource aggregation continues to the present. In March 2009, 3GPP RAN WG4 presented findings of an open Study Item (SI) investigating the performance of HSDPA and HSUPA under several aggregation scenarios, namely:

- Dual Cell HSDPA on two separate frequency bands
- Dual Cell HSDPA together with MIMO in a single frequency band
- Three and four carrier HSDPA for both single as well as two separate frequency bands
- Dual Carrier HSUPA on adjacent carriers

3GPP RAN WG4 confirmed that peak improvement rates for all the features were as expected, and further in certain modeled scenarios average user burst data rates are substantially improved compared to Release 8. 3GPP RAN WG4 noted that the Layer 2/Layer 3 impacts, and UE RF performance/complexity related implications especially for multi-band and multi-mode UEs, needed further investigation. Meanwhile, a parallel work group, 3GPP RAN WG1, did not identify any problems in its focus area that would make any of the studied techniques infeasible.[42] New Work Items (WIs) related to these features were adopted in March 2009, and are scheduled for finalization at the RAN #44 Plenary set for December 2009.

[42] *RAN1 Findings of the UTRA Multi-Carrier Evolution Study*, Third Generation Partnership Project, RP-090318 (March 2009), *document available for download at* http://www.3gpp.org/Radio-Access-Network-status-after.

Successful conclusion of Release 9 specifications would facilitate several important aggregation enhancements to what is currently embodied in Release 8. In particular, Release 9 would introduce Dual Carrier HSUPA (DC-HSUPA). In this scenario, DC-HSUPA is envisioned to operate only together with DC-HSDPA to enable bundling two adjacent 2x5 MHz UL/DL carrier pairs within the same spectrum band. This is depicted in Figure 16 below.

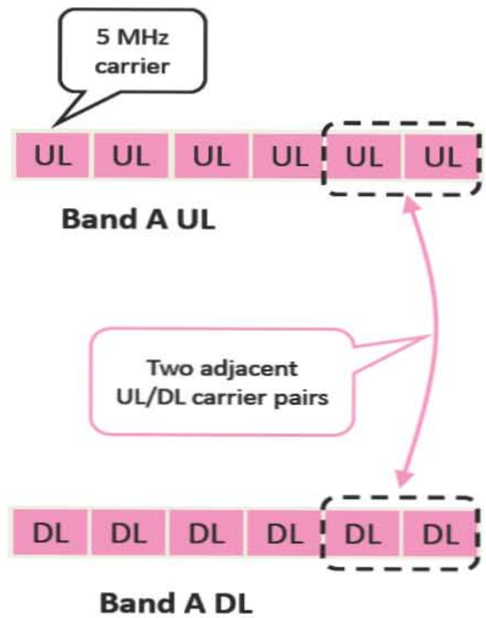


Figure 16. DC HSDPA/HSUPA - 2 UL and 2 DL Carriers (3GPP Release 9)

3.1.4 3GPP RELEASE 9 WOULD ALSO INTRODUCE DUAL-BAND HSDPA

Release 9 would also enable another important resource aggregation enhancement – Dual Carrier/Dual Band HSDPA (DC/DB HSDPA). This would enable the deployment of DC-HSDPA (which, per Release 8, pairs one 2x5 MHz UL carrier with two 2x5 MHz DL carriers), but now with the ability to locate the DL carriers on different frequency bands. This is illustrated in Figure 17 below.

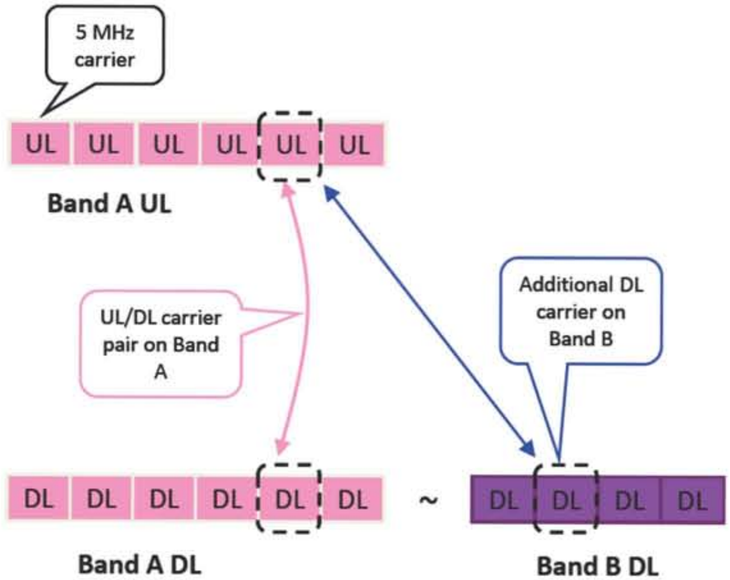
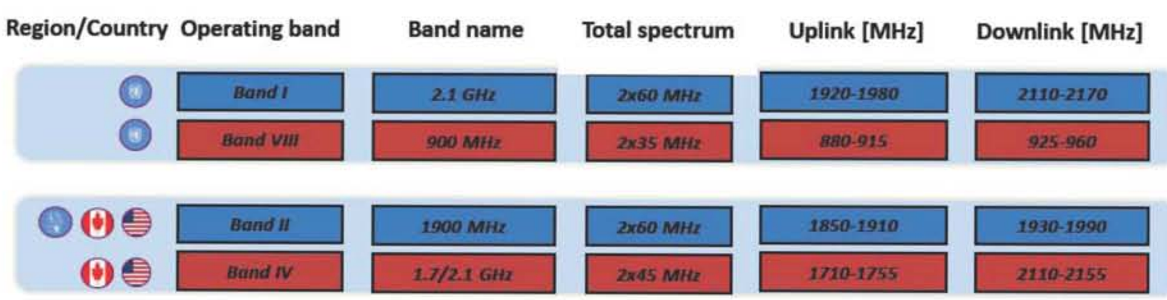


Figure 17. DC/DB HSDPA: 1 UL Carrier, 2 DL Carriers (3GPP Release 9)

3GPP has focused its initial work on DC/DB HSDPA on allowing aggregation across two sets of frequencies bands, as shown in the figure below. The first set would allow combining DL carriers in Band I (2.1 GHz) and Band VIII (900 MHz), and the second would permit coupling DL carriers in Band II (PCS) and Band IV (1.7/2.1 GHz or AWS-1) frequencies. The latter set of bands has already been auctioned in the U.S. and Canada. Moreover, a number of Latin American nations (including Argentina, Chile, Mexico and Colombia) are preparing to auction those frequencies starting in 2009. Other bands are being considered by 3GPP for introduction at a later date.



Region/Country	Operating band	Band name	Total spectrum	Uplink [MHz]	Downlink [MHz]
	Band I	2.1 GHz	2x60 MHz	1920-1980	2110-2170
	Band VIII	900 MHz	2x35 MHz	880-915	925-960
	Band II	1900 MHz	2x60 MHz	1850-1910	1930-1990
	Band IV	1.7/2.1 GHz	2x45 MHz	1710-1755	2110-2155

Figure 18. Band Combinations for 3GPP Release 9 DC/DB HSDPA

Initial studies have also commenced on the introduction of resource aggregation techniques for LTE-Advanced. 3GPP RAN WG4 has begun investigating possible UE RF architectures to enable four LTE-

Advanced resource aggregation scenarios for ITU-R submission purposes.[43] More information on this work can be found in *Appendix C* at the end of this document.

The current activity within 3GPP clearly indicates the technical direction towards inclusion of asymmetrical pairing and dual carrier aggregation options for use by wireless service providers. To capitalize on these approaches, designed to address growing needs for mobile broadband and asymmetrical Internet uplink/downlink data ratios, sound spectrum managements principles must govern, as explored in the next section.

4. SPECTRUM MANAGEMENT TRENDS

At the same time that awareness of 3GPP technology trends is promoted, there is a parallel and vital need to foster sound spectrum management policies. These go hand-in-hand with creating the appropriate environment in which multiple technologies can vie for preeminence in the market.

The coexistence of two mobile technologies operating in adjacent frequency bands, without sufficient protections for signal isolation, can lead to potentially severe interference problems due to practical limitations of the transmitter and receiver equipment. The interference problem can be particularly acute when the adjacent bands are the receiving band for one system and the transmitting band for the other system, for example, as is sometimes the case when TDD operations are considered adjacent to FDD operations, or similarly when unsynchronized TDD systems are adjacent to one another. In such adjacent band coexistence cases, the intersystem interference problem manifests through three primary mechanisms:

1. **Out-of-Band Emissions (OOBE)** are unwanted transmit emissions outside the nominal channel resulting from the modulation processes and non-linearities in the transmitter, but excluding spurious emissions. These emissions from the interfering transmitter create co-channel interference to the victim receiver which cannot be eliminated by the victim receiver (meaning that no amount of receiver filtering can remove the interference because it is in-band). The detrimental effects of OOBE can be reduced by increasing the suppression of the transmitter filter or by reducing the transmitted power levels for the interfering system.
2. **Adjacent channel interference** is due to the imperfect filtering on the victim receiver, which captures energy from frequencies that are outside its own nominal channel. If the interference levels are of sufficiently high power levels, then receiver overload (saturation) or blocking can occur. The adjacent channel interference can be reduced by increasing the suppression of the receiver filters or by limiting the power levels of the interfering system. The ability of a receiver to combat adjacent channel interference is usually quoted in terms of Adjacent Channel Selectivity (ACS) and Blocking specifications. In some cases, it is extremely difficult, if not impossible, to completely remove adjacent channel interference since practical filters need some amount of spectrum (e.g. guard bands) to achieve significant attenuation.

[43] *Study of UE architectures for LTE-A deployment Scenarios,* Third Generation Partnership Project, R4-091204 (March 2009), *document available for download at* http://ftp.3gpp.org/tsg_ran/WG4_Radio/TSGR4_50bis/Documents/.

3. **Spurious emissions** are emissions other than the desired transmit signal which are caused by undesired transmitter effects such as harmonics, parasitics, intermodulation products or frequency conversion products, but exclude out of band emissions. Harmonic emissions occur at multiples of the transmitter's fundamental carrier frequency due to nonlinearities in the processing; hence, they will often be far removed from the victim receive band. Parasitic emissions are undesired oscillations that can occur within the transmitter at frequencies typically far removed from the carrier frequency, so would often be expected to be far removed from the victim receive band. Intermodulation or frequency conversion products come from nonlinear mixing of various signals in the transmitter processing. In well designed transmitters, these products would typically be at levels below those of OOBE; therefore, spurious emissions are often not the dominant source of interference when mobile technologies are operated in adjacent bands.

Based on the above three interference mechanisms, appropriate protections need to be established to balance access to the spectrum with de-risking the potential for harmful interference. Such protections can include transmit emissions masks (i.e. transmitter filtering) and transmit power limitations.

4.1 TECHNICAL SPECIFICATIONS

The interference mechanisms described above require different treatment to effectively mitigate the potential for harmful interference, because the underlying causes of the interference are fundamentally different. There is no "one size fits all" solution for adjacent band interference problems. Instead, specific solutions are required that address the specific root causes of the interference.

For example, OOBE interference leaks through the transmit filter of the device causing the interference to the victim receiver. The result is radiation from the source terminal device inside of the victim downlink mobile receive band, causing co-channel interference. Under such circumstances, even a perfect brick wall filter on the victim receiver would not reject the OOBE interference because it arrives directly in the nominal receive channel. It is therefore a misnomer to assume that better receive filters on the victim receiver can solve such a problem − this OOBE interference mechanism *must* be controlled by the OOBE specifications defining the transmit filter performance of the interfering transmitter and by transmit power limitations for the interfering terminal device.

On the other hand, adjacent channel interference is received by the victim mobile due to the roll-off skirts of the victim receive filter. Some energy from adjacent channels leak into the victim receiver tuned to an adjacent channel. The adjacent channel energy acts as interference, reducing the carrier-to-interference ratio of the desired serving signal. If the adjacent channel interference is strong enough, then it can cause saturation overload or blocking of the victim receiver. Receiver saturation overload occurs when the interfering signal is so strong that it drives the receiver into the nonlinear operating region causing potentially severe degradation of the desired signal performance. The adjacent channel interference can be reduced through better receive filter or receiver specifications in the victim receiver, or by transmit power limitations for the interfering terminal device.

These two primary interference mechanisms are distinct and as such require uniquely different mitigation approaches. OOBE is caused by leakage from the interfering transmitter radiating directly into the victim receiver band causing co-channel interference; therefore it can only be controlled at the interfering source terminal device by appropriate OOBE specifications and transmit power limits. Adjacent channel interference results from leakage in the victim receive filter; therefore it can be controlled by the victim mobile receiver specifications or by transmit power limits on the perpetrating terminal device.

In sum, regulatory bodies and industry players must work together to establish appropriate rules which mitigate these interference problems, by addressing the specific causes through well-engineered selection of emissions specifications.

4.2 GUARD BANDS

Interference due to the coexistence of TDD and FDD systems operating in adjacent frequency bands can be especially acute because frequency separation cannot be used to isolate the uplinks and downlinks, meaning that sensitive receivers can be operating in close spectral, geographical and temporal proximity to transmitters. As the WiMAX Forum points out, "This scenario [FDD-TDD coexistence] includes the same interference paths found in the FDD-FDD scenario plus potentially crippling BS-to-BS [base station] and SS-to-SS [subscriber station] interference paths between the systems."[44] There are radio engineering practices to reduce or eliminate base-station-to-base-station interference because it is static.[45] However, mobile-to-mobile interference is another story altogether due to its dynamic nature. As the WiMAX Forum observes, "if the SSs [subscriber stations] are operated close enough to one another there is nothing that can be done to mitigate this [interference] problem."[46] When the TDD system is operating in a band adjacent to the FDD downlink, this most problematic mobile-to-mobile interference scenario occurs from TDD transmissions into FDD mobile receivers. As the WiMAX Forum clarifies the interference is asymmetrical: "... [I]f the TDD system operates in a channel adjacent to the FDD DL [downlink], the FDD SS suffers interference from the TDD SS, but not necessarily *vice versa*."[47] Furthermore, Ofcom reports that for TDD macrocells and even at extremely good FDD received powers (at or above -80 dBm), "TDD terminal stations operating in the first adjacent block with respect to a FDD terminal station can cause a significant (albeit graceful) degradation in throughput."[48]

Guard bands are commonly employed for maximizing the use of spectrum bands when providers operate in close proximity, generating a high likelihood for generating inter-system interference. As described in further detail previously, a current illustration involves the CEPT 2.6 GHz band plan and the technical rules developed for that band. Those rules mandate a separation of at least 5 MHz between the edges of TDD spectrum blocks and FDD spectrum blocks.[49] Further, the rules specify that these guard bands can be left unused or be used for "restricted" operations.[50] The restrictions specify base station transmit radiated power limits that are 36 dBs lower (a factor of almost 4000 times lower power) compared to

[44] *See Service Recommendations to Support Technology Neutral Allocations FDD/TDD* Coexistence, WiMAX Forum, (10 Apr. 2007) at p. 21 ("WiMAX Forum FDD/TDD Study"), *available at* *http://www.wimaxforum.org/technology/downloads/Service_Recs_Tech_Neutrality_-_FDD-TDD Coexistence.pdf*.

[45] *See e.g., The Cellular Radio Handbook: A Reference Guide for Cellular System Operation,* Neil J. Boucher, John Wiley & Sons Ltd. (Fourth Edition, 2001), at pp. 87-97.

[46] WiMAX Forum FDD/TDD Study at p. 21.

[47] *Id.*

[48] Ofcom 2008 2.6 GHz FDD/TDD Technical Report at p. 14.

[49] *See* EC 2008 2.6 GHz Harmonization Decision.

[50] *See* CEPT Report 19 at Appendix IV - Block Edge Masks for 2.6 GHz Band, pp. 69-77. CEPT further indicates therein that: "The development of the block edge masks for the 2.6 GHz band has been done on the basis that a 5 MHz restricted block is necessary between TDD and FDD UL blocks and between one TDD block and another." *See also Derivation of a Block Edge Mask (BEM) for Terminal Stations in the 2.6 GHz Frequency Band (2500-2690 MHz)*, CEPT Electronic Communications Committee, Report 131 (January 2009), *available at* http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP131.PDF.

unrestricted blocks.[51] As Ofcom has shown, these EC rules effectively limit TDD to being deployed in small picocells in these restricted blocks to reduce the potential for interference.[52]

This and other proceedings previously discussed (e.g. the U.S. AWS-III proceeding) illustrate the need to manage the potential interference issues associated with FDD and TDD adjacency, primarily through the creation of sufficient guard bands and secondarily by establishment of appropriate service rules.

Finally, it is critical for policy makers to utilize multiple methods of analysis to assess the risk of interference to achieve informed decision making on spectrum policy. Although statistical analyses, such as system simulations, can be powerful tools to analyze dynamic processes and complex statistical relationships, it is not by itself sufficient for assessing the risk of interference. Other approaches, such as deterministic studies, are required to gain a complete picture of interference potential to users. In fact, a detailed examination of recent studies of coexistence, demonstrates that using a variety of methods is extremely important for evaluating interference risks. [53]

[51] CEPT Report 19 at p. 74.
[52] *See* Ofcom 2008 2.6 GHz FDD/TDD Technical Report at p. 15 ("[I]t is likely that these restricted blocks could only be used for deployment of TDD pico-cells.").
[53] See *Ericsson Ex Parte Notice to FCC, Service Rules for Advanced Wireless Services in 2155-2175 MHz Band*, WT Docket No. 07-195(9 Sept. 9, 2008), *available at* http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6520066376.

5. CONCLUSION

Studies have persuasively shown that there is a significant impact of fragmented spectrum allocations on the cost and performance of mobile devices. These impacts hold true in virtually every corner of the globe. Handset cost and size constraints place limits on the number of bands and technologies that typical small and low-cost consumer wireless devices can incorporate. This means that support for fragmented spectrum allocations is frequently minimized in favor of the more common global bands.

Regulators have an important– and challenging – role in obtaining addition spectrum and bringing it to market to meet the demands of consumers. 3G Americas would offer that in undertaking this effort, regulators should bear in mind the following:

1. Spectrum should be harmonized and coordinated to the maximum extent feasible;
2. New spectrum should facilitate access by new technologies of all stripes;
3. At the same time, appropriate protections should be established for incumbent and/or adjacent service providers to protect against interference;
4. Spectrum policy should foster as far as possible the efficient use of spectrum; and
5. The rules covering the allocation, auction and deployment of spectrum should be predictable and transparent, prior to auctions.

Notwithstanding, where support for fragmented spectrum bands is pursued, regulatory bodies and industry players must work together to develop technological solutions and appropriate technical rules to balance access to these bands with service provider coexistence.

APPENDIX A: ABBREVIATIONS

2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
ARPU	Average Revenue per User
AWS	Advanced Wireless Services
Bits/s/Hz	Measure of spectral efficiency, determined by dividing the net bit rate or throughput by the bandwidth in Hertz
Bps	Bits per second
BRS	Broadband Radio Service
BSC	Base Station Controller
BTS	Base Transceiver Station
BW	Bandwidth
C/I	Carrier to Interference Ratio
CA	Carrier Aggregation
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CC	Component Carrier
CDMA	Code Division Multiple Access
CEPT	European Conference of Postal and Telecommunications Administrations (consists of policymakers and regulators from 48 states)
CITEL	Inter-American Telecommunications Commission (part of the Organization of American States)
CPE	Customer Premises Equipment
CS	Circuit Switched
dB	Decibel
dBm	Decibel ratio of watts to 1 milliwatt
DC-HSDPA	Dual Carrier High Speed Downlink Packet Access
DC-HSPA	Dual Carrier HSPA
DC-HSUPA	Dual Carrier High Speed Uplink Packet Access
DL	Downlink
DSL	Digital Subscriber Line
EC	European Commission
ECC	Electronic Communications Committee (CEPT committee comprised of telecommunications regulators from member states)
E–DCH	Enhanced Dedicated Channel (also known as HSUPA)
EDGE	Enhanced Data Rates for GSM Evolution
EPC	Evolved Packet Core, also known as SAE (refers to flatter-IP core network)
EPS	Evolved Packet System (the combination of the EPC/SAE and the LTE/EUTRAN)
EUTRA	Evolved Universal Terrestrial Radio Access
EUTRAN	Evolved Universal Terrestrial Radio Access Network (based on OFDMA)
EV-DO	One Carrier Evolved, Data Optimized
EV-DV	One Carrier Evolved, Data Voice

FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FOMA	Freedom of Mobile Multimedia Access (brand name for 3G services offered by Japanese mobile phone operator NTT DoCoMo)
GB	Gigabyte
Gbps	Gigabits per Second
GERAN	GSM EDGE Radio Access Network
GHz	Gigahertz
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GSMA	GSM Association
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access (HSDPA with HSUPA)
HSPA+	High Speed Packet Access Plus (also known as HSPA Evolution or Evolved HSPA)
HSUPA	High Speed Uplink Packet Access
Hz	Hertz
IEEE	Institute of Electrical and Electronic Engineers
IMT	International Mobile Telecommunications
IP	Internet Protocol
ISP	Internet Service Provider
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union, Radiocommunication Sector
Kbps	Kilobits per Second
kHz	Kilohertz
LTE	Long Term Evolution (evolved air interface based on OFDMA)
LTE-A	LTE-Advanced
Mbps	Megabits per Second
MHz	Megahertz
MIMO	Multiple-Input Multiple-Output
MSC	Mobile Switching Center
NGM	Next Generation Mobile
NRA	National Regulatory Authority
Ofcom	U.K. communications regulatory authority
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access (air interface)
OPEX	Operating Expenses
PCS	Personal Communications Service
PS	Packet Switched
QoS	Quality of Service
RAB	Radio Access Bearer
RAT	Radio Access Technology
RATG	Radio Access Technology Group (committee within the ITU-R)

RB	Radio Bearer
RAN	Radio Access Network
RAN1	Working group within 3GPP focused on physical layer specifications
RAN4	Working group within 3GPP focused on radio performance and protocol aspects
Rel-X	Release 99, Release 4, Release 5, etc. from 3GPP standardization
RF	Radio Frequency
RNC	Radio Network Controller
SC-FDMA	Single Carrier Frequency Division Multiple Access
SAE	System Architecture Evolution, also known as EPC
SGSN	Serving GPRS Support Node
SG	Study Group
SI	Study Item
SIR	Signal to Interference Ratio
SNR	Signal to Noise Ratio
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TS	Technical Specification
UE	User Equipment
UGC	User Generated Content
UL	Uplink
UMB	Ultra Mobile Broadband
UMTS	Universal Mobile Telecommunications System
UTRA	Universal Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
WCDMA	Wideband CDMA
WG	Working Group
WI	Work Item
WiMAX	Worldwide Interoperability for Microwave Access
WRC	World Radio Conference

APPENDIX B: REFERENCES

STANDARDS DOCUMENTS

RAN1 Findings of the UTRA Multi-Carrier Evolution Study, Third Generation Partnership Project, RP-090318 (March 2009), document available for download at http://www.3gpp.org/Radio-Access-Network-status-after

Study of UE architectures for LTE-A deployment Scenarios, Third Generation Partnership Project, R4-091204 (March 2009), document available for download at http://ftp.3gpp.org/tsg_ran/WG4_Radio/TSGR4_50bis/Documents/

POLICY & REGULATORY DOCUMENTS

Commission Decision of 13 June 2008 on the Harmonization of the 2500-2690 MHz Frequency Band for Terrestrial Systems Capable of Providing Electronic Communications Services in the Community, available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:163:0037:0041:EN:PDF

Report from CEPT to the European Commission in Response to the Mandate to Develop Least Restrictive Technical Conditions for Frequency Bands Addressed in the Context of WAPECS (21 Dec. 2007) , available at http://www.erodocdb.dk/Docs/doc98/official/Word/CEPTREP019.DOC.

Report from the Independent Spectrum Broker: Findings and Policy Proposals, Final Report (12 May 2009), *available at* http://www.culture.gov.uk/images/publications/ISB_final_report.pdf*Transforming the Digital Dividend Opportunity into Social Benefits and Economic Growth in Europe*, EC Consultation Document (10 Jul. 2009) available at http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/consultations/2009_digitaldividend/2009_0710_0904_digitaldividendconsultation.pdf

SELECTED BOOKS & ANALYSES

The Cellular Radio Handbook: A Reference Guide for Cellular System Operation, Neil J. Boucher (John Wiley & Sons Ltd., Fourth Edition, 2001)

Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update (29 Jan. 2009), available at http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html.

HSPA Performance and Evolution: A Practical Perspective, Pablo Tapia *et al.* (John Wiley & Sons Ltd., 2009)

Mobile Broadband for the Masses, McKinsey & Company *(February 2009),* available at http://hspa.gsmworld.com/upload/news/files/25032009113456.pdf

Mobile Broadband Spectrum Demand, Rysavy Research (Dec. 2008), available at http://www.rysavy.com/Articles/2008_12_Rysavy_Spectrum_Demand.pdf

RF Cost Economics for Handsets, RTT (Sept 2007), available at http://www.rttonline.com/home_frame.htm

APPENDIX C: LTE-ADVANCED RESOURCE AGGREGATION

3GPP RAN WG4 has begun investigating possible UE RF architectures to enable four LTE-Advanced resource aggregation scenarios for ITU-R submission purposes.[54] These scenarios are depicted in the figure below.

Deployment Scenario	Transmission BWs of LTE-A carriers	No of LTE-A component carriers	Bands for LTE-A carriers	Duplex modes
Single-band contiguous spec. alloc. @ 3.5GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Contiguous 2x20 MHz CCs DL: Contiguous 4x20 MHz CCs	3.5 GHz band	FDD
Single-band contiguous spec. alloc. @ Band 40 for TDD	100 MHz	Contiguous 5x20 MHz CCs	Band 40 (2.3 GHz)	TDD
Multi-band non-contiguous spec. alloc. @ Band 1, 3 and 7 for FDD	UL: 40 MHz DL: 40 MHz	UL/DL: Non-contiguous 10 MHz CC@Band 1 + 10 MHz CC@Band 3 + 20 MHz CC@Band 7	Band 3 (1.8 GHz) Band 1 (2.1 GHz) Band 7 (2.6 GHz)	FDD
Multi-band non-contiguous spec. alloc. @ Band 39, 34, and 40 for TDD	90 MHz	Non-contiguous 2x20 + 10 + 2x20 MHz CCs	Band 39 (1.8GHz) Band 34 (2.1GHz) Band 40 (2.3GHz)	TDD

Figure C.1. Possible UE RF Architectures for LTE-Advanced Resource Aggregation

Initial analysis has focused on UE complexity and power consumption for the resource aggregation scenarios in this chart. RAN WG4 has initially concluded that it would be beneficial for LTE-A feasibility study purposes to consider various device categories in order to enable a sufficient number of different UE categories in LTE-Advanced. One set of device categories presented by RAN WG4 is listed in the figure below.

[54] *Study of UE architectures for LTE-A deployment Scenarios,* Third Generation Partnership Project, R4-091204 (March 2009), *document available for download at* http://ftp.3gpp.org/tsg_ran/WG4_Radio/TSGR4_50bis/Documents/.

	Max bandwidth aggregation / [MHz]	Multiband aggregation / [number of bands]	DL MIMO rank	UL MIMO rank	Device category
Category A	10	1	1	1	Lowest cost mobile phone
Category B	20	1	1	1	Low cost mobile phone
Category C	20	1	2	1	mobile phone
Category D	40	1	2	1	mobile phone
Category E	40	2	2	1	Laptop/mini computer/mobile phone/hand held device
Category F	100	2	4	2	Laptop/mini computer
Category G	100	3	8	4	customer premises equipment

Figure C.2. Possible Device Categories Presented by RAN WG4 for LTE-Advanced

RAN WG 4 noted in particular that it envisions the need for an absolutely lowest cost terminal. This is reflected in Category A above, which represents even a simpler UE category than 3GPP Release 8 currently allows.

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